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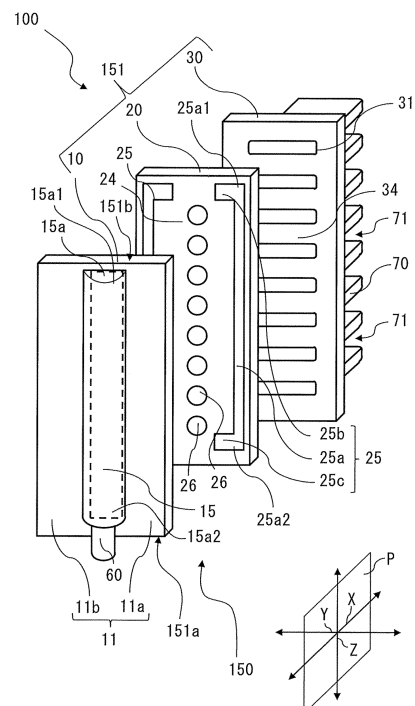
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(54) **HEAT EXCHANGER AND REFRIGERATION CYCLE APPARATUS**

(57) A heat exchanger includes a plurality of heat transfer tubes arranged at intervals in a first direction, and configured to circulate refrigerant in a second direction intersecting the first direction, and a refrigerant distributor connected to one end of each of the plurality of heat transfer tubes and configured to distribute the refrigerant to the plurality of heat transfer tubes. The refrigerant distributor includes, in its inside, a first flow path and a second flow path through which the refrigerant flows. The first flow path is formed so as to extend in the first direction, communicates with the plurality of heat transfer tubes, and is connected with an inflow tube configured to cause the refrigerant to flow into the refrigerant distributor. The second flow path is formed so as to extend in the first direction, with opposite ends thereof being connected with the first flow path, and is formed so as to be positioned in a third direction relative to the first flow path, when a direction intersecting a plane parallel to the first direction and to the second direction is defined as the third direction.

FIG. 3



## Description

## Technical Field

**[0001]** The present disclosure relates to a heat exchanger, and a refrigeration cycle apparatus including the heat exchanger.

## Background Art

**[0002]** Heat transfer tubes used in heat exchangers for air-conditioning apparatuses are becoming increasingly smaller to reduce the amount of refrigerant used or to improve heat exchanger performance. To reduce an increase in the pressure loss of refrigerant associated with the trend toward smaller heat transfer tubes, recent heat exchangers have increased number of passes (number of branches) in comparison to existing heat exchangers. Accordingly, such a heat exchanger is provided with a multi-pass refrigerant distributor (see, for example, Patent Literature 1). To achieve balance between heat exchanger performance and reduction of the amount of refrigerant used, a need exists for a compact refrigerant distributor that prevents or reduces maldistribution of refrigerant flow among individual passes, allows for reduced volume of the distribution flow path to reduce the amount of refrigerant used, and does not interfere with the installation space for the heat exchanger while ensuring increased heat transfer surface area.

**[0003]** A heat exchanger described in Patent Literature 1 includes multiple heat transfer tubes, a header manifold, and multiple fins. The heat transfer tubes are arranged side by side. The header manifold, which serves as a refrigerant distributor, is connected with one end of each heat transfer tube, and extends in the vertical direction. The fins are joined to the heat transfer tubes. The internal space of the header manifold is divided by a partition plate into a first space connected with one end of each heat transfer tube, and a second space located across the partition plate from the first space. A communication path is provided near the upper and lower ends of the partition plate to allow the first space and the second space to communicate with each other. Due to the above configuration of the heat exchanger described in Patent Literature 1, refrigerant is looped between the first space and the second space. By allowing refrigerant to loop between the first space and the second space, the heat exchanger described in Patent Literature 1 makes it possible to reduce maldistribution of refrigerant.

## Citation List

## Patent Literature

**[0004]** Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2015-68622

## Summary of Invention

## Technical Problem

**[0005]** In the heat exchanger described in Patent Literature 1, the first space defines a flow path through which two-phase gas-liquid refrigerant flows upward, and the second space defines a circulation flow path that directs refrigerant back to a lower portion from an upper portion of the heat exchanger. The first space and the second space are located in the direction in which the tube paths of the heat transfer tubes extend. The above configuration causes the refrigerant distributor described in Patent Literature 1 to increase in size in the direction in which the tube paths of the heat transfer tubes extend. This means that, due to structural constraints, the heat transfer tubes have a decreased length in the direction in which the tube paths of the heat transfer tubes extend, and consequently the heat transfer tubes have a decreased heat transfer surface area. This may potentially lead to deteriorated heat exchange performance of the heat exchanger described in Patent Literature 1 in comparison to existing heat exchangers.

**[0006]** The present disclosure is directed to addressing the above-mentioned problem. Accordingly, it is an object of the present disclosure to provide a heat exchanger and a refrigeration cycle apparatus that allow for increased heat transfer surface area of the heat transfer tubes, and include a compact refrigerant distributor that does not increase in size in the direction in which the tube paths of the heat transfer tubes extend.

## Solution to Problem

**[0007]** A heat exchanger according to an embodiment of the present disclosure includes a plurality of heat transfer tubes arranged at intervals in a first direction, and configured to circulate refrigerant in a second direction intersecting the first direction, and a refrigerant distributor connected to one end of each of the plurality of heat transfer tubes and configured to distribute the refrigerant to the plurality of heat transfer tubes. The refrigerant distributor includes, in its inside, a first flow path and a second flow path through which the refrigerant flows. The first flow path is formed so as to extend in the first direction, communicates with the plurality of heat transfer tubes, and is connected with an inflow tube configured to cause the refrigerant to flow into the refrigerant distributor. The second flow path is formed so as to extend in the first direction, with opposite ends thereof being connected with the first flow path, and is formed so as to be positioned in a third direction relative to the first flow path, when a direction intersecting a plane parallel to the first direction and to the second direction is defined as the third direction.

**[0008]** A refrigeration cycle apparatus according to an embodiment of the present disclosure includes a heat exchanger according to an embodiment of the present

disclosure.

#### Advantageous Effects of Invention

**[0009]** According to an embodiment of the present disclosure, the heat exchanger includes a refrigerant distributor having, inside the refrigerant distributor, a first flow path and a second flow path through which refrigerant flows. The second flow path is formed so as to extend in the first direction, with opposite ends thereof being connected with the first flow path. The second flow path is formed so as to be positioned in a third direction relative to the first flow path, when a direction intersecting a plane parallel to the first direction and to the second direction is defined as the third direction. The above-mentioned configuration of the heat exchanger helps to prevent or reduce an increase in the size of the refrigerant distributor in the second direction in which refrigerant is circulated, and allows the heat exchanger to be enlarged, within a range of structural constraints, in the direction in which the tube paths of the heat transfer tubes extend. The heat exchanger 100 according to an embodiment of the present disclosure thus allows for increased heat transfer surface area of the heat transfer tubes, and also allows the refrigerant distributor to be made compact without an increase in the size of the refrigerant distributor in the direction in which the tube paths of the heat transfer tubes extend.

#### Brief Description of Drawings

##### **[0010]**

[Fig. 1] Fig. 1 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus including a heat exchanger according to Embodiment 1.

[Fig. 2] Fig. 2 is a side view of the heat exchanger according to Embodiment 1, conceptually illustrating the configuration of major components of the heat exchanger.

[Fig. 3] Fig. 3 is an exploded perspective view of the heat exchanger according to Embodiment 1, conceptually illustrating the configuration of major components of the heat exchanger.

[Fig. 4] Fig. 4 illustrates, in cross-section, the configuration of a heat transfer tube forming the heat exchanger according to Embodiment 1.

[Fig. 5] Fig. 5 is a cross-sectional view of the heat exchanger according to Embodiment 1, conceptually illustrating where first and second flow paths of a refrigerant distributor forming the heat exchanger communicate with each other.

[Fig. 6] Fig. 6 conceptually illustrates how refrigerant flows within the refrigerant distributor forming the heat exchanger according to Embodiment 1.

[Fig. 7] Fig. 7 illustrates the distribution of flow rate of refrigerant within the refrigerant distributor forming

the heat exchanger according to Embodiment 1.

[Fig. 8] Fig. 8 is an exploded perspective view of a heat exchanger according to Embodiment 2, conceptually illustrating the configuration of major components of the heat exchanger.

[Fig. 9] Fig. 9 is a cross-sectional view of the heat exchanger according to Embodiment 2, conceptually illustrating where first and second flow paths of a refrigerant distributor forming the heat exchanger communicate with each other.

[Fig. 10] Fig. 10 conceptually illustrates how refrigerant flows within the refrigerant distributor forming the heat exchanger according to Embodiment 2.

[Fig. 11] Fig. 11 illustrates the distribution of flow rate of refrigerant within the refrigerant distributor forming the heat exchanger according to Embodiment 2.

[Fig. 12] Fig. 12 is an exploded perspective view of a heat exchanger according to Embodiment 3, conceptually illustrating the configuration of major components of the heat exchanger.

[Fig. 13] Fig. 13 is a cross-sectional view of the heat exchanger according to Embodiment 3, conceptually illustrating where first and second flow paths of a refrigerant distributor forming the heat exchanger communicate with each other.

[Fig. 14] Fig. 14 conceptually illustrates how refrigerant flows within the refrigerant distributor forming the heat exchanger according to Embodiment 3.

[Fig. 15] Fig. 15 illustrates the distribution of flow rate of refrigerant within the refrigerant distributor forming the heat exchanger according to Embodiment 3.

[Fig. 16] Fig. 16 is an exploded perspective view of a heat exchanger according to Embodiment 4, conceptually illustrating the configuration of major components of the heat exchanger.

[Fig. 17] Fig. 17 is a cross-sectional view of the heat exchanger according to Embodiment 4, conceptually illustrating where first and second flow paths of a refrigerant distributor forming the heat exchanger communicate with each other.

[Fig. 18] Fig. 18 conceptually illustrates how refrigerant flows within the refrigerant distributor forming the heat exchanger according to Embodiment 4.

[Fig. 19] Fig. 19 is an exploded perspective view of a heat exchanger according to Embodiment 5, conceptually illustrating the configuration of major components of the heat exchanger.

[Fig. 20] Fig. 20 is a conceptual side view of the interior of a refrigerant distributor illustrated in Fig. 19.

[Fig. 21] Fig. 21 is a cross-sectional view of the heat exchanger according to Embodiment 5, conceptually illustrating where first and second flow paths of the refrigerant distributor forming the heat exchanger communicate with each other.

[Fig. 22] Fig. 22 is a cross-sectional view of the heat exchanger according to Embodiment 5, conceptually illustrating where first and second flow paths of a modification of the refrigerant distributor forming the

heat exchanger communicate with each other.

[Fig. 23] Fig. 23 conceptually illustrates how refrigerant flows within the refrigerant distributor forming the heat exchanger according to Embodiment 5. Description of Embodiments

**[0011]** A heat exchanger 100 and a refrigeration cycle apparatus 200 according to Embodiment 1 will be described below with reference to the drawings or other illustrations. In the figures below including Fig. 1, the relative dimensions, shapes, and other features of various components may differ from those of the actual components. In the figures below, the same reference signs are used to indicate the same or corresponding elements or features throughout the specification. Although terms representing directions (e.g., "upper", "lower", "right", "left", "front", and "rear") are used as appropriate to facilitate understanding of the present disclosure, such terms are used for illustrative purposes only and not intended to limit the corresponding device or component to any particular placement or orientation. The relative positions of individual components, the directions of extension of individual components, and the directions of arrangement of individual components described herein basically correspond to those when an outdoor heat exchanger 105 is installed in a usable condition.

#### Embodiment 1

##### [Refrigeration Cycle Apparatus 200]

**[0012]** Fig. 1 is a refrigerant circuit diagram illustrating the configuration of the refrigeration cycle apparatus 200 including the heat exchanger 100 according to Embodiment 1. In Fig. 1, dotted arrows represent the direction in which refrigerant flows in a refrigerant circuit 110 during cooling operation, and solid arrows represent the direction in which refrigerant flows in the refrigerant circuit 110 during heating operation. Reference is made first to Fig. 1 to describe the refrigeration cycle apparatus 200 including the heat exchanger 100 described later.

**[0013]** In the following description of the embodiment, an air-conditioning apparatus will be described as an example of the refrigeration cycle apparatus 200. The refrigeration cycle apparatus 200 is used for, for example, refrigeration or air-conditioning purposes, such as for refrigerators or freezers, vending machines, air-conditioning apparatuses, refrigeration apparatuses, or water heaters. The illustrated refrigerant circuit 110 is given only by way of example, and configurations of circuit elements or other features are not limited to the particular details described below with reference to the embodiment but can be changed or modified as appropriate within the technical scope of the embodiment.

**[0014]** The refrigeration cycle apparatus 200 includes the refrigerant circuit 110. The refrigerant circuit 110 includes the following components connected sequentially via a refrigerant pipe; a compressor 101, a flow switching

device 102, an indoor heat exchanger 103, a pressure reducing device 104, and the outdoor heat exchanger 105. The refrigeration cycle apparatus 200 includes an outdoor unit 106, and an indoor unit 107. The outdoor unit 106 accommodates the following components: the compressor 101; the flow switching device 102; the outdoor heat exchanger 105; the pressure reducing device 104; and an outdoor fan 108 configured to supply outside air to the outdoor heat exchanger 105. The indoor unit 107 accommodates the indoor heat exchanger 103, and an indoor fan 109 configured to supply air to the indoor heat exchanger 103. The outdoor unit 106 and the indoor unit 107 are connected with each other via two extension pipes, an extension pipe 111 and an extension pipe 112, which form a portion of the refrigerant pipe.

**[0015]** The compressor 101 is a piece of fluid machinery that compresses sucked refrigerant and discharges the compressed refrigerant. The flow switching device 102 is, for example, a four-way valve. The flow switching device 102 is configured to, under control by a controller (not illustrated), switch the flows of refrigerant between cooling operation and heating operation. Refrigerant is a first heat exchange fluid.

**[0016]** The indoor heat exchanger 103 is a heat exchanger configured to cause heat exchange to be performed between refrigerant flowing inside the indoor heat exchanger 103, and indoor air supplied by the indoor fan 109. The indoor heat exchanger 103 functions as a condenser during heating operation, and functions as an evaporator during cooling operation.

**[0017]** The pressure reducing device 104 is, for example, an expansion valve, and configured to reduce the pressure of refrigerant. A suitable example of the pressure reducing device 104 is an electronic expansion valve whose opening degree is adjusted through control by the controller.

**[0018]** The outdoor heat exchanger 105 is a heat exchanger configured to cause heat exchange to be performed between refrigerant flowing inside the outdoor heat exchanger 105, and air supplied by the outdoor fan 108. The outdoor heat exchanger 105 functions as an evaporator during heating operation, and functions as a condenser during cooling operation. Air supplied by the outdoor fan 108 is an example of a second heat exchange fluid.

**[0019]** The heat exchanger 100 described later is used as at least one of the outdoor heat exchanger 105 and the indoor heat exchanger 103. A refrigerant distributor 150 connected with the heat exchanger 100 is desirably disposed at a location where the heat exchanger 100 receives an increased flow of liquid-phase refrigerant. Specifically, with respect to the flow of refrigerant in the refrigerant circuit 110, the refrigerant distributor 150 is desirably disposed near the inlet of the heat exchanger 100 functioning as an evaporator, that is, near the outlet of the heat exchanger 100 functioning as a condenser. Although the refrigerant distributor 150 is depicted in Fig. 1 as being used for both of the two heat exchangers 100

including the indoor heat exchanger 103 and the outdoor heat exchanger 105, the refrigerant distributor 150 may be used for only one of the two heat exchangers 100 including the indoor heat exchanger 103 and the outdoor heat exchanger 105.

#### [Operation of Refrigeration Cycle Apparatus 200]

**[0020]** Reference is now made to Fig. 1 to describe an example of how the refrigeration cycle apparatus 200 operates. During heating operation of the refrigeration cycle apparatus 200, high-pressure and high-temperature refrigerant in a gaseous state discharged from the compressor 101 flows via the flow switching device 102 into the indoor heat exchanger 103, where the refrigerant condenses through heat exchange with air supplied by the indoor fan 109. The condensed refrigerant changes into a high-pressure liquid state, and then leaves the indoor heat exchanger 103. The resulting refrigerant is turned into a low-pressure, two-phase gas-liquid state by the pressure reducing device 104. The low-pressure refrigerant in the two-phase gas-liquid state flows into the outdoor heat exchanger 105, where the refrigerant evaporates through heat exchange with air supplied by the outdoor fan 108. The evaporated refrigerant changes into a low-pressure gaseous state before being sucked into the compressor 101. During heating operation, if the pressure saturation temperature of the outdoor heat exchanger 105 is lower than or equal to the dew-point temperature of outdoor air and lower than or equal to the freezing point of water, frost forms on the outdoor heat exchanger 105.

**[0021]** During cooling operation of the refrigeration cycle apparatus 200, refrigerant flows in the refrigerant circuit 110 in a direction opposite to the direction of flow during heating operation. That is, during cooling operation of the refrigeration cycle apparatus 200, high-pressure and high-temperature refrigerant in a gaseous state discharged from the compressor 101 flows via the flow switching device 102 into the outdoor heat exchanger 105, where the refrigerant condenses through heat exchange with air supplied by the outdoor fan 108. The condensed refrigerant changes into a high-pressure liquid state, and then leaves the outdoor heat exchanger 105. The resulting refrigerant is then turned into a low-pressure, two-phase gas-liquid state by the pressure reducing device 104. The low-pressure refrigerant in the two-phase gas-liquid state flows into the indoor heat exchanger 103, where the refrigerant evaporates through heat exchange with air supplied by the indoor fan 109. The evaporated refrigerant changes into a low-pressure gaseous state before being sucked into the compressor 101.

#### [Outdoor Heat Exchanger 105]

**[0022]** Fig. 2 is a side view of the heat exchanger 100 according to Embodiment 1, conceptually illustrating the

configuration of major components of the heat exchanger 100. Fig. 3 is an exploded perspective view of the heat exchanger 100 according to Embodiment 1, conceptually illustrating the configuration of major components of the heat exchanger 100. Reference is now made to Figs. 2 and 3 to describe the heat exchanger 100 according to Embodiment 1. A hatched arrow F in Fig. 2 represents the direction of refrigerant flow in a first flow path portion 15 of the refrigerant distributor 150. If the refrigerant distributor 150 is used for the refrigeration cycle apparatus 200, the refrigerant distributor 150 is connected with an end of each of heat transfer tubes 70 that is an end through which refrigerant enters the heat transfer tube 70 when the heat exchanger 100 operates as an evaporator.

**[0023]** As illustrated in Fig. 2, the heat exchanger 100 includes multiple heat transfer tubes 70 configured to circulate refrigerant, and the refrigerant distributor 150 connected with one end of each of the heat transfer tubes 70 in a direction in which the tube path of the heat transfer tube 70 extends. The heat exchanger 100 also includes a refrigerant inflow tube 60 attached to a lower portion of the refrigerant distributor 150.

**[0024]** The heat transfer tubes 70 are arranged at intervals in a first direction (Z-axis direction), and configured to circulate refrigerant in a second direction (X-axis direction) intersecting the first direction (Z-axis direction). The heat transfer tubes 70 are flat tubes. Although the heat transfer tubes 70 will be described below as flat tubes, the heat transfer tubes 70 may not necessarily be flat tubes but may be, for example, circular tubes.

**[0025]** For the heat exchanger 100, the direction of arrangement of the heat transfer tubes 70, and the direction of extension of the refrigerant distributor 150 are each defined as a first direction (Z-axis direction). That is, the first direction is the direction in which the heat transfer tubes 70 are arranged. For the heat exchanger 100, the direction of arrangement of the heat transfer tubes 70, which is the first direction (Z-axis direction), is defined as the up-down direction. The up-down direction is, for example, the vertical direction. However, the direction of arrangement of the heat transfer tubes 70, which is defined as the first direction (Z-axis direction), may not necessarily be the up-down direction or the vertical direction. Alternatively, the direction of arrangement of the heat transfer tubes 70 may be a direction inclined relative to the vertical direction, or may be the horizontal direction.

**[0026]** For the heat exchanger 100, the direction in which the tube paths of the heat transfer tubes 70 extend is defined as a second direction (X-axis direction). The tube paths of the heat transfer tubes 70 represent refrigerant passages 72 described later (see Fig. 4). Accordingly, the second direction (X-axis direction) is also the direction of refrigerant flow through the tube paths of the heat transfer tubes 70. For the heat exchanger 100, the direction in which the tube paths of the heat transfer tubes 70 extend, which is the second direction (X-axis direction), is defined as the horizontal direction. However, the

direction in which the tube paths of the heat transfer tubes 70 extend, which is defined as the second direction (X-axis direction), may not necessarily be the horizontal direction. Alternatively, the direction in which the tube paths of the heat transfer tubes 70 extend may be a direction inclined relative to the horizontal direction, or may be the up-down direction including the vertical direction.

**[0027]** A gap 71 through which air flows is defined between two adjacent heat transfer tubes 70. Heat transfer fins 75 may be disposed between two adjacent heat transfer tubes 70 as illustrated in Fig. 2. A portion of the heat exchanger 100 may have the heat transfer fins 75 each serving as a heat transfer facilitating part, and a portion of the heat exchanger 100 may have a region where adjacent heat transfer tubes 70 are not connected with each other by a heat transfer facilitating part.

**[0028]** Adjacent heat transfer tubes 70 may have no heat transfer fin 75, and may not be connected with each other by such a heat transfer facilitating part. A heat transfer facilitating part is a part used to facilitate heat transfer. An exemplary heat transfer facilitating part is a plate fin such as the heat transfer fin 75, or a corrugated fin. Accordingly, the outdoor heat exchanger 105 may be implemented as a so-called finless heat exchanger.

**[0029]** If the heat exchanger 100 functions as an evaporator for the refrigeration cycle apparatus 200, in each of the heat transfer tubes 70, refrigerant flows through each tube path inside the heat transfer tube 70 from one end to the other end in the direction in which the tube path extends. If the heat exchanger 100 functions as a condenser for the refrigeration cycle apparatus 200, in each of the heat transfer tubes 70, refrigerant flows through each tube path inside the heat transfer tube 70 from the other end to the one end in the direction in which the tube path extends.

(Heat Transfer Tubes 70)

**[0030]** Fig. 4 illustrates, in cross-section, the configuration of each heat transfer tube 70 forming the heat exchanger 100 according to Embodiment 1. Fig. 4 illustrates a cross-section perpendicular to the direction in which each heat transfer tube 70 extends. As illustrated in Fig. 4, each heat transfer tube 70 has a cross-sectional shape that is flattened in one direction, such as an oval shape.

**[0031]** Each heat transfer tube 70 has a first side end 70a and a second side end 70b, and a pair of flat surfaces 70c and 70d. In the cross-sectional view of Fig. 4, the first side end 70a is connected with one end of the flat surface 70c and with one end of the flat surface 70d. In the above-mentioned cross-sectional view, the second side end 70b is connected with the other end of the flat surface 70c and with the other end of the flat surface 70d.

**[0032]** The first side end 70a is a side end located upstream, that is, at the leading edge with respect to the flow of air passing through the heat exchanger. The second side end 70b is a side end located downstream, that

is, at the trailing edge with respect to the flow of air passing through the heat exchanger. In the following description, a direction perpendicular to the direction of extension of each heat transfer tube 70 and along the flat surface 70c and the flat surface 70d is sometimes referred to as long-axis direction of the heat transfer tube 70.

**[0033]** Each heat transfer tube 70 includes multiple refrigerant passages 72 arranged in the long-axis direction between the first side end 70a and the second side end 70b. Each heat transfer tube 70 is a flat multi-port tube with multiple refrigerant passages 72 arranged in the direction of air flow and through which refrigerant passes. Each of the refrigerant passages 72 extends in parallel to the direction of extension of the heat transfer tubes 70.

(Refrigerant Distributor 150)

**[0034]** With reference back to Figs. 2 and 3, the refrigerant distributor 150 will be described below. The refrigerant distributor 150 has a body 151 extending in the first direction (Z-axis direction). The body 151 of the refrigerant distributor 150 is connected with one end of each of the heat transfer tubes 70. The refrigerant distributor 150 distributes refrigerant to each of the heat transfer tubes 70 connected with the body 151.

**[0035]** The body 151 of the refrigerant distributor 150 is disposed in the direction of arrangement of the heat transfer tubes 70 such that the body 151 extends in the up-down direction. The body 151 has a distribution flow path extending in the first direction and defined inside the body 151 to distribute refrigerant to each of the heat transfer tubes 70. The body 151 of the refrigerant distributor 150 has a refrigerant inlet 18 that receives the refrigerant inflow tube 60 inserted into the refrigerant inlet 18, and multiple insertion holes 31 that each receive the corresponding one of the heat transfer tubes 70 inserted into the insertion hole 31.

**[0036]** The refrigerant inlet 18 is located at or near one end 151a of the body 151 in the first direction. The insertion holes 31 are defined in a side of the body 151 that is connected with the heat transfer tubes 70. The insertion holes 31 are arranged at intervals in the first direction (Z-axis direction) in one-to-one correspondence to the heat transfer tubes 70.

**[0037]** The body 151 of the refrigerant distributor 150 includes a first plate-shaped part 10, a second plate-shaped part 20, and a third plate-shaped part 30. The first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 are each made of a flat metal plate formed into a strip elongated in one direction. The respective outer edges of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 have identical contours. The first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 are each disposed with the direction of its plate thickness being parallel to the direction in which the tube paths of the heat transfer tubes 70 extend, that is, with its plate plane being

perpendicular to the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0038]** In the body 151 of the refrigerant distributor 150, the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 are stacked in this order from the farthest to the closest to the heat transfer tubes 70. In the body 151, the first plate-shaped part 10 is located farthest to the heat transfer tubes 70, and the third plate-shaped part 30 is located closest to the heat transfer tubes 70.

**[0039]** The second plate-shaped part 20 is disposed between the first plate-shaped part 10 and the heat transfer tubes 70, and adjacent to the first plate-shaped part 10 and the third plate-shaped part 30. The third plate-shaped part 30 is disposed between the second plate-shaped part 20 and the heat transfer tubes 70, and adjacent to the second plate-shaped part 20. The third plate-shaped part 30 is connected with one end of each of the heat transfer tubes 70.

**[0040]** Each adjacent two of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 are joined to each other by brazing. The first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 are each disposed with its longitudinal direction being aligned with the first direction (Z-axis direction).

**[0041]** Fig. 5 is a cross-sectional view of the heat exchanger 100 according to Embodiment 1, conceptually illustrating where first and second flow paths of the refrigerant distributor 150 forming the heat exchanger 100 communicate with each other. The direction of plate thickness of each of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 is the up-down direction in Fig. 5, which coincides with the direction in which the tube paths of the heat transfer tubes 70 extend. The lateral direction of each of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30 is the left-right direction in Fig. 5, which coincides with the long-axis direction of each heat transfer tube 70. The configuration of the body 151 of the refrigerant distributor 150 will be further described below with reference to Figs. 3 and 5.

**[0042]** As illustrated in Figs. 3 and 5, the first plate-shaped part 10 has the first flow path portion 15 that bulges away from the heat transfer tubes 70. The first flow path portion 15 is tubular in shape, with a space defined inside its bulge. Although the first plate-shaped part 10 and the first flow path portion 15 of the refrigerant distributor 150 are formed as an integral component, the first plate-shaped part 10 and the first flow path portion 15 may be formed as separate components.

**[0043]** The first flow path portion 15 extends in the longitudinal direction of the first plate-shaped part 10 from one longitudinal end of the first plate-shaped part 10 to the other longitudinal end. The first flow path portion 15 has the shape of a semicylinder. The first flow path portion 15 is closed at both ends in the direction of extension of the first flow path portion 15. When viewed in cross-

section perpendicular to the first direction (Z-axis direction), the first flow path portion 15 has a semicircular shape, a semielliptical shape, or a semioval shape. However, the cross-sectional shape of the first flow path portion 15 may not necessarily be semicircular, semielliptical, or semioval, but may be, for example, rectangular.

**[0044]** The first plate-shaped part 10 has a flat plate portion 11a and a flat plate portion 11b formed in the shape of a flat plate and located across the first flow path portion 15 from each other. The flat plate portion 11a and the flat plate portion 11b each extend in the longitudinal direction of the first plate-shaped part 10 from one longitudinal end of the first plate-shaped part 10 to the other longitudinal end. In other words, the first flow path portion 15 is located between the flat plate portion 11a and the flat plate portion 11b, and bulges relative to the flat plate portion 11a and the flat plate portion 11b in a direction opposite to the location of the heat transfer tubes 70. The first flow path portion 15 is open on its side near the heat transfer tubes 70. In the following description, the flat plate portion 11a and the flat plate portion 11b will be sometimes generically referred to as flat plate portion 11.

**[0045]** The first flow path portion 15 has, in its inside, a main flow path 15a extending in the up-down direction along the length of the first plate-shaped part 10. The main flow path 15a corresponds to a first flow path of the refrigerant distributor 150. The main flow path 15a serving as the first flow path is connected with the refrigerant inflow tube 60, which is connected with the refrigerant inlet 18. The main flow path 15a extends in the first direction (Z-axis direction) in which the heat transfer tubes 70 are arranged.

**[0046]** When viewed in the direction of plate thickness of the first plate-shaped part 10, the main flow path 15a serving as the first flow path extends while intersecting each of the heat transfer tubes 70. The main flow path 15a serving as the first flow path communicates with the tube paths of the heat transfer tubes 70 via distribution holes 26 described later, which are provided in the second plate-shaped part 20.

**[0047]** When viewed in cross-section perpendicular to the first direction (Z-axis direction), the main flow path 15a has a semicircular shape, a semielliptical shape, or a semioval shape. That is, the main flow path 15a is a space having the shape of a semicircular cylinder, a semielliptical cylinder, or a semioval cylinder. However, the cross-sectional shape of the main flow path 15a may not necessarily be semicircular, semielliptical, or semioval, but may be, for example, rectangular.

**[0048]** As described above, the main flow path 15a serving as the first flow path is formed so as to extend in the first direction (Z-axis direction), communicates with the heat transfer tubes 70, and is connected, at a lower end 15a2 in the first direction, with the refrigerant inflow tube 60 configured to cause refrigerant to flow into the refrigerant distributor 150. Two-phase gas-liquid refrigerant entering the main flow path 15a via the refrigerant inflow tube 60 flows upward in the main flow path 15a so

as to travel from the one end 151a of the body 151 toward the other end 151b, and is distributed to each of the heat transfer tubes 70.

**[0049]** The lower end of the first flow path portion 15 is connected with the refrigerant inflow tube 60. The main flow path 15a, and the internal space of the refrigerant inflow tube 60 communicate with each other. The refrigerant inflow tube 60 is configured to cause two-phase gas-liquid refrigerant to flow into the main flow path 15a when the heat exchanger 100 acts as an evaporator. The location of connection between the refrigerant inflow tube 60 and the first flow path portion 15 corresponds to the refrigerant inlet 18 through which refrigerant flows into the refrigerant distributor 150. When the heat exchanger 100 functions as a condenser, liquid refrigerant flows downward in the main flow path 15a, and exits the heat exchanger 100 through the refrigerant inflow tube 60.

**[0050]** The second plate-shaped part 20 has a sub-flow path 25, and the distribution holes 26. A direction intersecting a plane P parallel to the first direction (Z-axis direction) and the second direction (X-axis direction) is defined as a third direction. The third direction includes the Y-axis direction. With respect to the third direction (Y-axis direction), each distribution hole 26 is located in the vicinity of the middle of the second plate-shaped part 20, and the sub-flow path 25 is located in the vicinity of each end of the second plate-shaped part 20. That is, with respect to the third direction (Y-axis direction), each distribution hole 26 is located in the vicinity of the middle of the second plate-shaped part 20, and the sub-flow path 25 is disposed beside both sides of the distribution hole 26. The sub-flow path 25 and the distribution holes 26 of the second plate-shaped part 20 may not necessarily be located at the above-mentioned positions in the second plate-shaped part 20. A part of the sub-flow path 25 disposed beside one side of the distribution holes 26, and a part of the sub-flow path 25 disposed beside the other side of the distribution holes 26 may communicate with each other at least in their respective one end portions in the first direction.

**[0051]** The sub-flow path 25 is provided in the second plate-shaped part 20 so as to extend in the first direction (Z-axis direction). That is, the sub-flow path 25 is provided along the length of the second plate-shaped part 20 so as to extend in the up-down direction. The sub-flow path 25 corresponds to a second flow path of the refrigerant distributor 150. The sub-flow path 25 serving as the second flow path is provided in the body 151 of the refrigerant distributor 150 such that the sub-flow path 25 is connected at both ends with the main flow path 15a serving as the first flow path. The sub-flow path 25 defines a refrigerant flow path that provides communication between an upper end 15a1 of the main flow path 15a and the lower end 15a2 such that refrigerant that has reached the upper end 15a1 of the main flow path 15a is returned to the lower end 15a2 where the refrigerant inlet 18 is located. In the body 151 of the refrigerant distributor 150, the main flow path 15a and the sub-flow path 25 define a circulation

flow path for refrigerant.

**[0052]** The body 151 of the refrigerant distributor 150 has the main flow path 15a and the sub-flow path 25 that are defined inside the body 151 and through which refrigerant flows. As described above, the main flow path 15a corresponds to the first flow path, and the sub-flow path 25 corresponds to the second flow path. The sub-flow path 25 serving as the second flow path is located in the third direction relative to the main flow path 15a serving as the first flow path. That is, the main flow path 15a and the sub-flow path 25 are located upstream and downstream in the direction of airflow created by the outdoor fan 108 or the indoor fan 109 illustrated in Fig. 1.

**[0053]** The sub-flow path 25 has a middle portion 25a, an inlet portion 25b, and an outlet portion 25c. The middle portion 25a defines a flow path extending in the first direction (Z-axis direction). The inlet portion 25b is located at one end 25a1 of the middle portion 25a in the first direction (Z-axis direction). The outlet portion 25c is located at the other end 25a2 of the middle portion 25a in the first direction (Z-axis direction). The inlet portion 25b and the outlet portion 25c are each provided in the body 151 of the refrigerant distributor 150 as a flow path extending in the third direction (Y-axis direction).

**[0054]** In the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30, the middle portion 25a of the sub-flow path 25 is sandwiched between the flat plate portion 11 of the first plate-shaped part 10, and a flat plate portion 34 of the third plate-shaped part 30.

**[0055]** Opposite ends of the sub-flow path 25 are defined by the inlet portion 25b and the outlet portion 25c. In the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30, the inlet portion 25b and the outlet portion 25c are sandwiched between the first flow path portion 15, and the flat plate portion 34 of the third plate-shaped part 30. Accordingly, the inlet portion 25b and the outlet portion 25c communicate with the main flow path 15a, which is the first flow path defined by the first flow path portion 15. By contrast, the middle portion 25a of the sub-flow path 25 does not communicate with the main flow path 15a serving as the first flow path.

**[0056]** In the body 151 of the refrigerant distributor 150, the sub-flow path 25 serving as the second flow path has the inlet portion 25b and the outlet portion 25c. The sub-flow path 25 is thus connected at its both ends with the main flow path 15a serving as the first flow path. More specifically, in the body 151 of the refrigerant distributor 150, the inlet portion 25b of the sub-flow path 25 serving as the second flow path communicates with the upper end 15a1 of the main flow path 15a. In the body 151 of the refrigerant distributor 150, the outlet portion 25c of the sub-flow path 25 serving as the second flow path communicates with the lower end 15a2 of the main flow path 15a.

**[0057]** Refrigerant passes through the inlet portion 25b when flowing from the main flow path 15a serving as the



first flow path into the sub-flow path 25 serving as the second flow path. That is, refrigerant flows into the inlet portion 25b from the main flow path 15a serving as the first flow path. Refrigerant passes through the outlet portion 25c when flowing from the sub-flow path 25 serving as the second flow path into the main flow path 15a serving as the first flow path. That is, refrigerant exits through the outlet portion 25c into the main flow path 15a serving as the first flow path. In the body 151 of the refrigerant distributor 150, the sub-flow path 25 serving as the second flow path does not communicate with insertion holes 31, which will be described later, of the third plate-shaped part 30.

**[0058]** The second plate-shaped part 20 has multiple distribution holes 26 each defining a circular opening. The distribution holes 26 define flow paths between the main flow path 15a and the heat transfer tubes 70, and are configured to distribute refrigerant to each of the heat transfer tubes 70. Each of the distribution holes 26 is a through-hole extending through the second plate-shaped part 20 in the direction of plate thickness of the second plate-shaped part 20. The distribution holes 26 are arranged in the first direction (Z-axis direction), which coincides with the longitudinal direction of the second plate-shaped part 20. The distribution holes 26 each define a through-hole extending through the second plate-shaped part 20. The distribution holes 26 are disposed in one-to-one correspondence to the heat transfer tubes 70.

**[0059]** Although the opening defined by each distribution hole 26 is described above as having a circular shape, the opening may not necessarily have a circular shape. Alternatively, for example, the opening may have a semicircular shape, a semielliptical shape, a semioval shape, or a rectangular shape. The distribution holes 26 define flow paths with the same cross-sectional area. However, the distribution holes 26 may not necessarily define flow paths with the same cross-sectional area, but may define flow paths with different cross-sectional areas.

**[0060]** Although the second plate-shaped part 20 of the body 151 of the refrigerant distributor 150 according to Embodiment 1 is described above as having multiple distribution holes 26, the second plate-shaped part 20 may have only a single distribution hole 26. In this case, the single distribution hole 26 extends in the first direction (Z-axis direction) in such a way that the distribution hole 26 corresponds to multiple heat transfer tubes 70.

**[0061]** When viewed in the direction of plate thickness of the second plate-shaped part 20, each of the distribution holes 26 overlaps the main flow path 15a of the first plate-shaped part 10. When viewed in the direction of plate thickness of the second plate-shaped part 20, each of the distribution holes 26 overlaps the corresponding one of the insertion holes 31, which will be described later, of the third plate-shaped part 30. Further, when viewed in the direction of plate thickness of the second plate-shaped part 20, each of the distribution holes 26 overlaps the corresponding one of the heat transfer tubes 70.

Therefore, in the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30, the distribution holes 26 are located between the heat transfer tubes 70, and the main flow path 15a serving as the first flow path. The main flow path 15a of the first plate-shaped part 10, and each of the heat transfer tubes 70 communicate with each other via the corresponding one of the distribution holes 26.

**[0062]** The second plate-shaped part 20 has a blocking portion 24 in the form of a flat plate. When viewed in the direction of plate thickness of the second plate-shaped part 20, the blocking portion 24 partially overlaps the main flow path 15a of the first plate-shaped part 10. The blocking portion 24 serves to prevent the main flow path 15a and each of the heat transfer tubes 70 from communicating with each other directly rather than via the corresponding distribution hole 26.

**[0063]** The third plate-shaped part 30 has multiple insertion holes 31 each configured to receive one end of the corresponding one of the heat transfer tubes 70 inserted into the insertion hole 31. Each of the insertion holes 31 is a through-hole extending through the third plate-shaped part 30 in the direction of plate thickness of the third plate-shaped part 30.

**[0064]** The insertion holes 31 are arranged in parallel in the up-down direction along the length of the third plate-shaped part 30. The insertion holes 31 are provided independently of each other in one-to-one correspondence to the heat transfer tubes 70. Each insertion hole 31 defines an opening with a flattened shape that conforms to the outer circumferential shape of the corresponding heat transfer tube 70. The entire circumference of the opening edge of each insertion hole 31 is joined by brazing to the outer circumferential surface of the corresponding heat transfer tube 70.

**[0065]** The third plate-shaped part 30 has the flat plate portion 34 in the form of a flat plate. The flat plate portion 34 corresponds to a portion of the third plate-shaped part 30 that, when viewed in the direction of plate thickness of the third plate-shaped part 30, overlaps the sub-flow path 25 of the second plate-shaped part 20. The sub-flow path 25 serving as the second flow path is blocked by the flat plate portion 34 and the flat plate portion 11 in the second direction (X-axis direction).

**[0066]** In the body 151 of the refrigerant distributor 150, the main flow path 15a serving as the first flow path, and each end of the sub-flow path 25 serving as the second flow path overlap each other in the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30. In the body 151 of the refrigerant distributor 150, the main flow path 15a serving as the first flow path, each distribution hole 26, and each insertion hole 31 overlap each other in the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30.

**[0067]** Fig. 6 conceptually illustrates how refrigerant

flows within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 1. Reference is now made to an example of how the refrigerant distributor 150 according to Embodiment 1 operates when the heat exchanger 100 functions as an evaporator for the refrigeration cycle apparatus 200.

**[0068]** When the refrigeration cycle apparatus 200 is in heating operation, refrigerant flows into the refrigerant distributor 150 in a two-phase gas-liquid state. The two-phase gas-liquid refrigerant flows into the body 151 through the refrigerant inflow tube 60 illustrated in Figs. 2 and 6. Then, as represented by an arrow UF in Fig. 6, the refrigerant travels vertically upward in the main flow path 15a, which is defined in the first plate-shaped part 10, from the one end 151a toward the other end 151b. As the refrigerant travels vertically upward, the refrigerant passes through each distribution hole 26 of the second plate-shaped part 20 and then through each insertion hole 31 of the third plate-shaped part 30 for distribution to each heat transfer tube 70.

**[0069]** Refrigerant that accumulates in an upper portion of the main flow path 15a flows into the inlet portion 25b defined in the second plate-shaped part 20 and communicating with the upper end 15a1 of the main flow path 15a. At this time, as represented by an arrow OF, the refrigerant flows outward in the third direction from the main flow path 15a serving as the first flow path toward the sub-flow path 25 serving as the second flow path. Then, as represented by an arrow DF, the refrigerant entering through the inlet portion 25b of the sub-flow path 25 flows downward in the direction of gravity in the middle portion 25a of the sub-flow path 25 defined in the second plate-shaped part 20.

**[0070]** Upon reaching the lower end of the middle portion 25a of the sub-flow path 25, the refrigerant exits the sub-flow path 25 into the main flow path 15a through the outlet portion 25c communicating with the lower end 15a2 of the main flow path 15a. At this time, as represented by an arrow IF, the refrigerant flows inward in the third direction from the sub-flow path 25 serving as the second flow path toward the main flow path 15a serving as the first flow path. After exiting through the outlet portion 25c into the main flow path 15a, the exiting refrigerant, together with the refrigerant flowing into the body 151 through the refrigerant inflow tube 60, travels vertically upward in the main flow path 15a, and is distributed to each heat transfer tube 70.

**[0071]** Fig. 7 illustrates the distribution of flow rate of refrigerant within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 1. In Fig. 7, the horizontal axis represents refrigerant flow rate [kg/h], and the vertical axis represents the distance [m] from the refrigerant inlet 18 in the first direction in which the heat transfer tubes 70 are arranged.

**[0072]** In Fig. 7, a dotted line A represents the flow rate at which refrigerant flows in the main flow path 15a if no sub-flow path 25 is present, and a solid line B represents the flow rate at which refrigerant flows in the main flow

path 15a if the sub-flow path 25 is present. An alternate long and short dash line C represents a case where the flow rate of refrigerant in the main flow path 15a is constant in the up-down direction. If the flow rate of refrigerant in the main flow path 15a is constant in the up-down direction, then the flow rate of refrigerant into each of the heat transfer tubes 70 arranged in the first direction is constant. Accordingly, the closer the flow rate of refrigerant in the main flow path 15a is to the flow rate of refrigerant represented by the alternate long and short dash line C, the more desirable.

**[0073]** As represented by the dotted line A, if the body 151 is not provided with the sub-flow path 25 serving as the second flow path, liquid refrigerant accumulates in an upper portion of the main flow path 15a serving as the first flow path. This results in comparatively more liquid refrigerant being distributed in the upper portion of the main flow path 15a serving as the first flow path.

**[0074]** By contrast, if the body 151 is provided with the sub-flow path 25 serving as the second flow path, liquid refrigerant that accumulates in an upper portion of the main flow path 15a returns to a lower portion of the main flow path 15a by way of the sub-flow path 25. Thus, as represented by an arrow MU between the dotted line A and the solid line B, the flow rate of refrigerant decreases in the upper portion of the main flow path 15a as the refrigerant returns to the lower portion of the main flow path 15a. Further, as represented by an arrow MD between the dotted line A and the solid line B, the flow rate of refrigerant increases in the lower portion of the main flow path 15a as the refrigerant returns to the lower portion from the upper portion of the main flow path 15a. Consequently, as represented by the solid line B, the flow rate at which refrigerant flows in the main flow path 15a if the sub-flow path 25 is present is closer to the flow rate represented by the alternate long and short dash line C, than is the flow rate at which refrigerant flows in the main flow path 15a if no sub-flow path 25 is present. Therefore, the refrigerant distributor 150 with the sub-flow path 25 allows for uniform distribution of refrigerant to each heat transfer tube 70, in comparison to a refrigerant distributor without the sub-flow path 25.

[Advantageous Effects of Heat Exchanger 100]

**[0075]** The heat exchanger 100 includes the refrigerant distributor 150 that includes the main flow path 15a and the sub-flow path 25 through which refrigerant flows. The sub-flow path 25 serving as the second flow path is formed so as to extend in the first direction (Z-axis direction), with opposite ends thereof being connected with the main flow path 15a serving as the first flow path. The sub-flow path 25 serving as the second flow path is formed so as to be positioned in the third direction relative to the main flow path 15a serving as the first flow path, when a direction intersecting the plane P parallel to the first direction (Z-axis direction) and the second direction (X-axis direction) is defined as the third direction. The

above-mentioned configuration of the heat exchanger 100 helps to prevent or reduce an increase in the size of the refrigerant distributor 150 in the second direction in which refrigerant is circulated, and allows the heat exchanger 100 to be enlarged, within a range of structural constraints, in the second direction in which the tube paths of the heat transfer tubes 70 extend. Therefore, the heat exchanger 100 allows for increased heat transfer surface area of the heat transfer tubes 70, and also allows the refrigerant distributor 150 to be made compact without an increase in the size of the refrigerant distributor 150 in the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0076]** The heat exchanger 100 allows for increased heat transfer surface area of the heat transfer tubes 70, in comparison to a heat exchanger having first and second flow paths that are provided in the direction in which the tube paths of the heat transfer tubes 70 extend. The heat exchanger 100 thus allows for improved heat exchange performance, in comparison to a heat exchanger having first and second flow paths that are provided in the direction in which the tube paths of the heat transfer tubes 70 extend. Therefore, the heat exchanger 100 provides improved mitigation of refrigerant maldistribution with respect to changes in refrigerant flow rate or quality that depend on the operating condition of an air-conditioning apparatus. This leads to improved distribution robustness, that is, the ability to accommodate a wider range of refrigerant flow rate or other conditions.

**[0077]** The heat exchanger 100 has the sub-flow path 25. The presence of the sub-flow path 25 ensures that when an operating condition of the air-conditioning apparatus causes liquid refrigerant to accumulate in an upper portion of the main flow path 15a, the refrigerant is circulated from the upper portion of the main flow path 15a to the lower portion of the main flow path 15a. This helps to prevent or reduce maldistribution of refrigerant. The heat exchanger 100 including the refrigerant distributor 150 with the sub-flow path 25 thus allows for uniform distribution of refrigerant to each heat transfer tube 70, in comparison to a heat exchanger that includes a refrigerant distributor without the sub-flow path 25. This results in improved heat exchange performance of the heat exchanger 100 in comparison to a heat exchanger that includes a refrigerant distributor without the sub-flow path 25.

**[0078]** In the refrigerant distributor 150, in the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third plate-shaped part 30, the main flow path 15a and each end of the sub-flow path 25 overlap each other, and the main flow path 15a, each distribution hole 26, and each insertion hole 31 overlap each other. The above-mentioned configuration of the heat exchanger 100 helps to prevent or reduce an increase in the size of the refrigerant distributor 150 in the second direction in which the tube paths of the heat transfer tubes 70 extend, and allows the heat exchanger 100 to be enlarged, within a range of structural constraints,

in the second direction in which the tube paths of the heat transfer tubes 70 extend. Therefore, the heat exchanger 100 allows for increased heat transfer surface area of the heat transfer tubes 70, and also allows the refrigerant distributor 150 to be made compact without an increase in the size of the refrigerant distributor 150 in the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0079]** Opposite ends of the sub-flow path 25 serving as the second flow path are defined by the inlet portion 25b where refrigerant flows into the sub-flow path 25 from the main flow path 15a serving as the first flow path, and the outlet portion 25c where refrigerant exits the sub-flow path 25 into the main flow path 15a serving as the first flow path. The inlet portion 25b and the outlet portion 25c extend in the third direction. The above-mentioned configuration of the heat exchanger 100 helps to prevent or reduce an increase in the size of the refrigerant distributor 150 in the second direction in which the tube paths of the heat transfer tubes 70 extend, and allows the heat exchanger 100 to be enlarged, within a range of structural constraints, in the second direction in which the tube paths of the heat transfer tubes 70 extend. Therefore, the heat exchanger 100 allows for increased heat transfer surface area of the heat transfer tubes 70, and also allows the refrigerant distributor 150 to be made compact without an increase in the size of the refrigerant distributor 150 in the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0080]** The sub-flow path 25 serving as the second flow path is disposed beside both sides of the distribution holes 26 in the third direction. The above-mentioned configuration of the heat exchanger 100 helps to prevent or reduce an increase in the size of the refrigerant distributor 150 in the second direction in which the tube paths of the heat transfer tubes 70 extend, and allows the heat exchanger 100 to be enlarged, within a range of structural constraints, in the second direction in which the tube paths of the heat transfer tubes 70 extend. Therefore, the heat exchanger 100 allows for increased heat transfer surface area of the heat transfer tubes 70, and also allows the refrigerant distributor 150 to be made compact without an increase in the size of the refrigerant distributor 150 in the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0081]** Multiple distribution holes 26 are provided in the first direction (Z-axis direction). Each of the distribution holes 26 serves as a restriction hole with high flow resistance in the refrigerant flow path located between the main flow path 15a, which is the first flow path, and each of the heat transfer tubes 70. When the heat exchanger functions as an evaporator, each distribution hole 26 serves as a restriction hole. As a result, the pressure in the main flow path 15a rises, which causes an increase in the differential pressure between the main flow path 15a and each individual insertion hole 31. This evens out the differential pressure between the main flow path 15a and the higher positioned insertion holes 31, and the dif-

ferential pressure between the main flow path 15a and the lower positioned insertion holes 31. As a result, refrigerant in the main flow path 15a is distributed evenly to each insertion hole 31, and consequently distributed evenly to each heat transfer tube 70.

#### Embodiment 2

**[0082]** Fig. 8 is an exploded perspective view of the heat exchanger 100 according to Embodiment 2, conceptually illustrating the configuration of major components of the heat exchanger 100. Fig. 9 is a cross-sectional view of the heat exchanger 100 according to Embodiment 2, conceptually illustrating where the first and second flow paths of the refrigerant distributor 150 forming the heat exchanger 100 communicate with each other. Components identical in function and operation to the components described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. The heat exchanger 100 according to Embodiment 2 differs from the heat exchanger 100 according to Embodiment 1 in that the refrigerant distributor 150 further includes a fourth plate-shaped part 40 and a fifth plate-shaped part 50.

**[0083]** The body 151 of the refrigerant distributor 150 includes the first plate-shaped part 10, the second plate-shaped part 20, the third plate-shaped part 30, the fourth plate-shaped part 40, and the fifth plate-shaped part 50. The fourth plate-shaped part 40 and the fifth plate-shaped part 50 are each made of a flat metal plate formed into a strip elongated in one direction. The respective outer edges of the first plate-shaped part 10, the second plate-shaped part 20, the third plate-shaped part 30, the fourth plate-shaped part 40, and the fifth plate-shaped part 50 have identical contours. The first plate-shaped part 10, the second plate-shaped part 20, the third plate-shaped part 30, the fourth plate-shaped part 40, and the fifth plate-shaped part 50 are each disposed with the direction of its plate thickness being parallel to the direction in which the tube paths of the heat transfer tubes 70 extend. That is, the first plate-shaped part 10, the second plate-shaped part 20, the third plate-shaped part 30, the fourth plate-shaped part 40, and the fifth plate-shaped part 50 are each disposed with its plate plane being perpendicular to the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0084]** In the body 151 of the refrigerant distributor 150, the first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30 are stacked in this order from the farthest to the closest to the heat transfer tubes 70. In the body 151, the first plate-shaped part 10 is located farthest to the heat transfer tubes 70, and the third plate-shaped part 30 is located closest to the heat transfer tubes 70.

**[0085]** The fourth plate-shaped part 40 is disposed between the first plate-shaped part 10 and the second plate-shaped part 20, and the plate plane of the fourth plate-

shaped part 40 is adjacent to the plate plane of the first plate-shaped part 10 and the plate plane of the second plate-shaped part 20. The fifth plate-shaped part 50 is disposed between the second plate-shaped part 20 and the third plate-shaped part 30, and the plate plane of the fifth plate-shaped part 50 is adjacent to the plate plane of the second plate-shaped part 20 and the plate plane of the third plate-shaped part 30.

**[0086]** Adjacent two of the first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30 are joined to each other by brazing. The first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30 are each disposed with its longitudinal direction being aligned with the first direction (Z-axis direction).

**[0087]** The fourth plate-shaped part 40 has communication holes 45, and second distribution holes 46. The communication holes 45 are located between the main flow path 15a serving as the first flow path, and each end of the sub-flow path 25. The second distribution holes 46 are located between the main flow path 15a serving as the first flow path, and the second distribution holes 46. The communication holes 45 and the second distribution holes 46 are through-holes.

**[0088]** In the fourth plate-shaped part 40, two communication holes 45 are provided near the one end 151a, and two communication holes 45 are provided near the other end 151b. The communication holes 45 provided near the one end 151a serve as an outlet through which refrigerant exits the sub-flow path 25 into the main flow path 15a. The communication holes 45 provided near the other end 151b serve as an inlet through which refrigerant flows from the main flow path 15a into the sub-flow path 25. Although each communication hole 45 is depicted in Fig. 8 as a through-hole defining a rectangular opening, this is not intended to limit the shape of the opening defined by the communication hole 45 to a rectangle.

**[0089]** The communication holes 45 are located between the main flow path 15a and the inlet portion 25b in the direction of stacking of the first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30. The communication holes 45 are also located between the main flow path 15a and the outlet portion 25c in the direction of stacking of the first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30. Therefore, each communication hole 45 provides communication between the main flow path 15a serving as the first flow path and the sub-flow path 25 serving as the second flow path, and serves as a flow path that interconnects the main flow path 15a serving as the first flow path and the sub-flow path 25 serving as the second flow path.

**[0090]** The fourth plate-shaped part 40 has multiple

second distribution holes 46 each defining a circular opening. Each second distribution hole 46 is located in the vicinity of the middle of the fourth plate-shaped part 40 in the third direction (Y-axis direction). The second distribution holes 46 define flow paths between the main flow path 15a and the heat transfer tubes 70, together with the distribution holes 26 of the second plate-shaped part 20 and third distribution holes 51, which will be described later, of the fifth plate-shaped part 50. Each second distribution hole 46 is configured to distribute refrigerant to the corresponding heat transfer tube 70.

**[0091]** Each of the second distribution holes 46 is a through-hole extending through the fourth plate-shaped part 40 in the direction of plate thickness of the fourth plate-shaped part 40. The second distribution holes 46 are arranged in the first direction (Z-axis direction), which coincides with the longitudinal direction of the fourth plate-shaped part 40. The second distribution holes 46 each define a through-hole extending through the fourth plate-shaped part 40, and are disposed in one-to-one correspondence to the heat transfer tubes 70. The second distribution holes 46 are provided in one-to-one correspondence to the distribution holes 26 of the second plate-shaped part 20. Further, the second distribution holes 46 are provided in one-to-one correspondence to the third distribution holes 51, which will be described later, of the fifth plate-shaped part 50.

**[0092]** Although the opening defined by each second distribution hole 46 is described above as having a circular shape, the opening may not necessarily have a circular shape. Alternatively, for example, the opening may have a semicircular shape, a semielliptical shape, a semioval shape, or a rectangular shape. The second distribution holes 46 define flow paths with the same cross-sectional area. However, the second distribution holes 46 may not necessarily define flow paths with the same cross-sectional area, but may define flow paths with different cross-sectional areas.

**[0093]** Although the fourth plate-shaped part 40 of the body 151 of the refrigerant distributor 150 according to Embodiment 2 is described above as having multiple second distribution holes 46, the fourth plate-shaped part 40 may have only a single second distribution hole 46. In this case, the single second distribution hole 46 is formed so as to extend in the first direction (Z-axis direction) such that the second distribution hole 46 corresponds to multiple heat transfer tubes 70.

**[0094]** When viewed in the direction of plate thickness of the fourth plate-shaped part 40, each of the second distribution holes 46 overlaps the main flow path 15a of the first plate-shaped part 10. When viewed in the direction of plate thickness of the fourth plate-shaped part 40, each of the second distribution holes 46 overlaps the corresponding one of the distribution holes 26 of the second plate-shaped part 20. When viewed in the direction of plate thickness of the fourth plate-shaped part 40, each of the second distribution holes 46 overlaps the corresponding one of the third distribution holes 51 of the fifth

plate-shaped part 50. When viewed in the direction of plate thickness of the fourth plate-shaped part 40, each of the second distribution holes 46 overlaps the corresponding one of the insertion holes 31 of the third plate-shaped part 30. When viewed in the direction of plate thickness of the fourth plate-shaped part 40, each of the second distribution holes 46 overlaps the corresponding one of the heat transfer tubes 70.

**[0095]** Therefore, in the direction of stacking of the first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30, the second distribution holes 46 are located between the heat transfer tubes 70, and the main flow path 15a serving as the first flow path. The main flow path 15a of the first plate-shaped part 10, and each of the heat transfer tubes 70 communicate with each other via the corresponding one of the second distribution holes 46.

**[0096]** The fourth plate-shaped part 40 has a blocking portion 44 in the form of a flat plate. When viewed in the direction of plate thickness of the fourth plate-shaped part 40, the blocking portion 44 partially overlaps the main flow path 15a of the first plate-shaped part 10. The blocking portion 44 serves to prevent the main flow path 15a and each of the heat transfer tubes 70 from communicating with each other directly rather than via the corresponding second distribution hole 46.

**[0097]** The blocking portion 44 covers a portion of the sub-flow path 25 from a side of the sub-flow path 25 that is located near the first plate-shaped part 10. The blocking portion 44 covers at least the middle portion 25a of the sub-flow path 25 from a side of the sub-flow path 25 that is located near the first plate-shaped part 10. The blocking portion 44 constitutes a portion of the tube path defining the sub-flow path 25.

**[0098]** The fifth plate-shaped part 50 has the third distribution holes 51 located between the distribution holes 26 and the insertion holes 31. Each third distribution hole 51 is a through-hole.

**[0099]** The fifth plate-shaped part 50 has multiple third distribution holes 51 each defining a circular opening. Each third distribution hole 51 is located in the vicinity of the middle of the fifth plate-shaped part 50 in the third direction (Y-axis direction). The third distribution holes 51 define flow paths between the main flow path 15a and the heat transfer tubes 70, together with the distribution holes 26 of the second plate-shaped part 20 and the second distribution holes 46 of the fourth plate-shaped part 40. Each third distribution hole 51 is configured to distribute refrigerant to the corresponding heat transfer tube 70.

**[0100]** Each of the third distribution holes 51 is a through-hole extending through the fifth plate-shaped part 50 in the direction of plate thickness of the fifth plate-shaped part 50. The third distribution holes 51 are arranged in the first direction (Z-axis direction), which coincides with the longitudinal direction of the fifth plate-shaped part 50. The third distribution holes 51 each de-

fine a through-hole extending through the fifth plate-shaped part 50, and are disposed in one-to-one correspondence to the heat transfer tubes 70. The third distribution holes 51 are provided in one-to-one correspondence to the distribution holes 26 of the second plate-shaped part 20. Further, the third distribution holes 51 are provided in one-to-one correspondence to the second distribution holes 46 defined in the fourth plate-shaped part 40.

**[0101]** Although the opening defined by each third distribution hole 51 is described above as having a circular shape, the opening may not necessarily have a circular shape. Alternatively, for example, the opening may have a semicircular shape, a semielliptical shape, a semioval shape, or a rectangular shape. The third distribution holes 51 define flow paths with the same cross-sectional area. However, the third distribution holes 51 may not necessarily define flow paths with the same cross-sectional area, but may define flow paths with different cross-sectional areas.

**[0102]** Although the fifth plate-shaped part 50 of the body 151 of the refrigerant distributor 150 according to Embodiment 1 is described above as having multiple third distribution holes 51, the fifth plate-shaped part 50 may have only a single third distribution hole 51. In this case, the single third distribution hole 51 is formed so as to extend in the first direction (Z-axis direction) such that the third distribution hole 51 corresponds to multiple heat transfer tubes 70.

**[0103]** When viewed in the direction of plate thickness of the fifth plate-shaped part 50, each of the third distribution holes 51 overlaps the main flow path 15a of the first plate-shaped part 10. When viewed in the direction of plate thickness of the fifth plate-shaped part 50, each of the third distribution holes 51 overlaps the corresponding one of the distribution holes 26 of the second plate-shaped part 20. When viewed in the direction of plate thickness of the fifth plate-shaped part 50, each of the third distribution holes 51 overlaps the corresponding one of the second distribution holes 46 of the fourth plate-shaped part 40. When viewed in the direction of plate thickness of the fifth plate-shaped part 50, each of the third distribution holes 51 overlaps the corresponding one of the insertion holes 31 of the third plate-shaped part 30. When viewed in the direction of plate thickness of the fifth plate-shaped part 50, each of the third distribution holes 51 overlaps the corresponding one of the heat transfer tubes 70.

**[0104]** Therefore, in the direction of stacking of the first plate-shaped part 10, the fourth plate-shaped part 40, the second plate-shaped part 20, the fifth plate-shaped part 50, and the third plate-shaped part 30, the third distribution holes 51 are located between the heat transfer tubes 70, and the main flow path 15a serving as the first flow path. The main flow path 15a of the first plate-shaped part 10, and each of the heat transfer tubes 70 communicate with each other via the corresponding one of the third distribution holes 51.

**[0105]** The fifth plate-shaped part 50 has a blocking portion 53 in the form of a flat plate. When viewed in the direction of plate thickness of the fifth plate-shaped part 50, the blocking portion 53 partially overlaps the main flow path 15a of the first plate-shaped part 10. The blocking portion 53 serves to prevent the main flow path 15a and each of the heat transfer tubes 70 from communicating with each other directly rather than via the corresponding third distribution hole 51.

**[0106]** The blocking portion 53 covers a portion of the sub-flow path 25 from a side of the sub-flow path 25 that is located near the third plate-shaped part 30. The blocking portion 53 covers at least the middle portion 25a of the sub-flow path 25 from a side of the sub-flow path 25 that is located near the third plate-shaped part 30. The blocking portion 53 forms a portion of the tube path defining the sub-flow path 25.

**[0107]** Fig. 10 conceptually illustrates how refrigerant flows within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 2. When the refrigeration cycle apparatus 200 is in heating operation, refrigerant flows into the refrigerant distributor 150 in a two-phase gas-liquid state. The two-phase gas-liquid refrigerant flows into the body 151 through the refrigerant inflow tube 60. Then, as represented by the arrow UF in Fig. 10, the refrigerant travels vertically upward in the main flow path 15a, which is defined in the first plate-shaped part 10, from the one end 151a toward the other end 151b. As the refrigerant travels vertically upward, a portion of the refrigerant passes through the second distribution holes 46 of the fourth plate-shaped part 40, the distribution holes 26 of the second plate-shaped part 20, and the third distribution holes 51 of the fifth plate-shaped part 50 in this order before being distributed to the heat transfer tubes 70 by way of the insertion holes 31 defined in the third plate-shaped part 30.

**[0108]** Refrigerant that accumulates in an upper portion of the main flow path 15a flows into the inlet portion 25b of the second plate-shaped part 20 via the communication holes 45 that communicate with the upper end 15a1 of the main flow path 15a. At this time, as represented by the arrow OF, the refrigerant flows outward in the third direction from the main flow path 15a serving as the first flow path toward the sub-flow path 25 serving as the second flow path. Then, as represented by the arrow DF, the refrigerant entering through the inlet portion 25b of the sub-flow path 25 flows downward in the direction of gravity in the middle portion 25a of the sub-flow path 25 defined in the second plate-shaped part 20.

**[0109]** Upon reaching the lower end of the middle portion 25a of the sub-flow path 25, the refrigerant exits through the outlet portion 25c into the main flow path 15a via the communication holes 45 that communicate with the lower end 15a2 of the main flow path 15a. At this time, as represented by the arrow IF, the refrigerant flows inward in the third direction from the sub-flow path 25 serving as the second flow path toward the main flow path 15a serving as the first flow path. After exiting

through the outlet portion 25c into the main flow path 15a, the exiting refrigerant, together with the refrigerant flowing into the body 151 through the refrigerant inflow tube 60, travels vertically upward in the main flow path 15a, and is distributed to each heat transfer tube 70.

**[0110]** Fig. 11 illustrates the distribution of flow rate of refrigerant within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 2. In Fig. 11, the horizontal axis represents refrigerant flow rate [kg/h], and the vertical axis represents the distance [m] from the refrigerant inlet 18 in the first direction in which the heat transfer tubes 70 are arranged.

**[0111]** As with Embodiment 1, if the body 151 is provided with the sub-flow path 25 serving as the second flow path, liquid refrigerant that accumulates in an upper portion of the main flow path 15a returns to a lower portion of the main flow path 15a by way of the sub-flow path 25. Thus, as represented by the arrow MU between the dotted line A and the solid line B, the flow rate of refrigerant decreases in the upper portion of the main flow path 15a as the refrigerant returns to the lower portion of the main flow path 15a. Further, as represented by the arrow MD between the dotted line A and the solid line B, the flow rate of refrigerant increases in the lower portion of the main flow path 15a as the refrigerant returns to the lower portion from the upper portion of the main flow path 15a. Consequently, as represented by the solid line B, the flow rate at which refrigerant flows in the main flow path 15a if the sub-flow path 25 is present is closer to the flow rate represented by the alternate long and short dash line C, than is the flow rate at which refrigerant flows in the main flow path 15a if no sub-flow path 25 is present. Therefore, the refrigerant distributor 150 with the sub-flow path 25 allows refrigerant to be evenly distributed to each heat transfer tube 70, in comparison to a refrigerant distributor without the sub-flow path 25.

#### [Advantageous Effects of Heat Exchanger 100]

**[0112]** The refrigerant distributor 150 includes the fourth plate-shaped part 40, and the fifth plate-shaped part 50. The fourth plate-shaped part 40 has the communication holes 45, which are located between the main flow path 15a serving as the first flow path and each end of the sub-flow path 25, and the second distribution holes 46, which are located between the main flow path 15a serving as the first flow path and the distribution holes 26. The fifth plate-shaped part 50 has the third distribution holes 51 located between the distribution holes 26 and the insertion holes 31.

**[0113]** In the body 151 of the refrigerant distributor 150, the above-mentioned through-holes are provided in the fourth plate-shaped part 40 and the fifth plate-shaped part 50. This ensures that the flow of refrigerant between the main flow path 15a and the sub-flow path 25, and the flow of refrigerant from the main flow path 15a to the heat transfer tubes 70 are not hindered. Further, in the body 151 of the refrigerant distributor 150, the tube path of the

sub-flow path 25 can be defined by the blocking portion 44 of the fourth plate-shaped part 40 and by the blocking portion 53 of the fifth plate-shaped part 50. That is, for the body 151 of the refrigerant distributor 150, the flat plate portion 11 of the first plate-shaped part 10, and the flat plate portion 34 of the third plate-shaped part 30 are not required for defining the tube path of the sub-flow path 25.

**[0114]** Consequently, the sub-flow path 25 can be provided in the second plate-shaped part 20 such that, when viewed in the direction of stacking of the plate-shaped parts, the sub-flow path 25 overlaps the main flow path 15a of the first plate-shaped part 10, and the insertion holes 31 of the third plate-shaped part 30. In other words, in the body 151 of the refrigerant distributor 150, the sub-flow path 25 provided in the second plate-shaped part 20 can be increased in width in the third direction (Y-axis direction). This leads to increased volume of the sub-flow path 25. As a result, in the refrigerant distributor 150 of the heat exchanger 100, the pressure loss in the sub-flow path 25 decreases and, consequently, when the circulation flow rate is high, a large amount of refrigerant that accumulates in the upper portion is allowed to circulate. This helps to prevent or reduce refrigerant maldistribution, and consequently improve the performance of the heat exchanger 100.

#### Embodiment 3

**[0115]** Fig. 12 is an exploded perspective view of the heat exchanger 100 according to Embodiment 3, conceptually illustrating the configuration of major components of the heat exchanger 100. Fig. 13 is a cross-sectional view of the heat exchanger 100 according to Embodiment 3, conceptually illustrating where the first and second flow paths of the refrigerant distributor 150 forming the heat exchanger 100 communicate with each other. Fig. 14 conceptually illustrates how refrigerant flows within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 3. Components identical in function and operation to the components described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. The heat exchanger 100 according to Embodiment 3 differs from the heat exchanger 100 according to Embodiment 1 in that, unlike for the outlet portion 25c of the heat exchanger 100 according to Embodiment 1, for an outlet portion 25c1 of the heat exchanger 100 according to Embodiment 3, the angle of the tube axis of the outlet portion 25c1 is specified.

**[0116]** As illustrated in Fig. 12, the sub-flow path 25 has the middle portion 25a, the inlet portion 25b, and the outlet portion 25c1. The middle portion 25a defines a flow path extending in the first direction (Z-axis direction). The outlet portion 25c1 is located at the other end 25a2 of the middle portion 25a in the first direction (Z-axis direction).

**[0117]** A tube axis TA of the outlet portion 25c1 is in-

clined toward a diagonal line DL of the second plate-shaped part 20 relative to the first direction (Z-axis direction) and the third direction (Y-axis direction). Therefore, as represented by the arrow IF and the arrow UF in Fig. 14, the outlet portion 25c1 is inclined relative to the first direction and the third direction such that the direction of flow of refrigerant exiting the outlet portion 25c1 has a vector component of the direction of flow of refrigerant exiting the refrigerant inflow tube 60. That is, refrigerant exiting the outlet portion 25c1 is directed along the flow of refrigerant flowing in the main flow path 15a.

**[0118]** In the plate plane of the second plate-shaped part 20, an outlet angle  $\theta$ , which is an angle between the direction of the tube axis TA of the outlet portion 25c1 and the direction of gravity GD, is greater than or equal to 90 degrees.

**[0119]** Fig. 15 illustrates the distribution of flow rate of refrigerant within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 3. In Fig. 12, the horizontal axis represents refrigerant flow rate [kg/h], and the vertical axis represents the distance [m] from the refrigerant inlet 18 in the first direction in which the heat transfer tubes 70 are arranged.

**[0120]** As with Embodiment 1, if the body 151 is provided with the sub-flow path 25 serving as the second flow path, liquid refrigerant that accumulates in an upper portion of the main flow path 15a returns to a lower portion of the main flow path 15a by way of the sub-flow path 25. Thus, as represented by the arrow MU between the dotted line A and the solid line B, the flow rate of refrigerant decreases in the upper portion of the main flow path 15a as the refrigerant returns to the lower portion of the main flow path 15a. Further, as represented by the arrow MD between the dotted line A and the solid line B, the flow rate of refrigerant increases in the lower portion of the main flow path 15a as the refrigerant returns to the lower portion from the upper portion of the main flow path 15a. Consequently, as represented by the solid line B, the flow rate at which refrigerant flows in the main flow path 15a if the sub-flow path 25 is present is closer to the flow rate represented by the alternate long and short dash line C, than is the flow rate at which refrigerant flows in the main flow path 15a if no sub-flow path 25 is present. Therefore, the refrigerant distributor 150 with the sub-flow path 25 allows refrigerant to be evenly distributed to each heat transfer tube 70, in comparison to a refrigerant distributor without the sub-flow path 25.

#### [Advantageous Effects of Heat Exchanger 100]

**[0121]** As represented by the arrow IF and the arrow UF in Fig. 14, the outlet portion 25c1 is inclined relative to the first direction and the third direction such that the direction of flow of refrigerant exiting the outlet portion 25c1 has a vector component of the direction of flow of refrigerant exiting the refrigerant inflow tube 60. Consequently, the outlet portion 25c1 of the sub-flow path 25 provided in the second plate-shaped part 20 is directed

upward in the vertical direction, and the flow vector of refrigerant when the flow of refrigerant joins the main flow path 15a from the sub-flow path 25 is thus directed upward. This results in increased upward inertial force of refrigerant. The refrigerant distributor 150 of the heat exchanger 100 therefore facilitates circulation of refrigerant in the main flow path 15a and the sub-flow path 25. The refrigerant distributor 150 of the heat exchanger 100 allows for circulation of a large amount of refrigerant that accumulates in an upper portion of the main flow path 15a. This helps to prevent or reduce maldistribution of refrigerant.

#### Embodiment 4

**[0122]** Fig. 16 is an exploded perspective view of the heat exchanger 100 according to Embodiment 4, conceptually illustrating the configuration of major components of the heat exchanger 100. Fig. 17 is a cross-sectional view of the heat exchanger 100 according to Embodiment 4, conceptually illustrating where the first and second flow paths of the refrigerant distributor 150 forming the heat exchanger 100 communicate with each other. Fig. 18 conceptually illustrates how refrigerant flows within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 4. Components identical in function and operation to the components described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. The heat exchanger 100 according to Embodiment 4 differs from the heat exchanger 100 according to Embodiment 1 in that Embodiment 4 further specifies the configuration of the main flow path 15a serving as the first flow path.

**[0123]** As described above, the first flow path portion 15 has the main flow path 15a defined inside the first flow path portion 15. In the heat exchanger 100 according to Embodiment 4, the main flow path 15a serving as the first flow path decreases in cross-sectional area from the lower end 15a2, which is one end communicating with the refrigerant inflow tube 60, toward the upper end 15a1, which is the other end. With the first direction (Z-axis direction) defined as the up-down direction, the main flow path 15a decreases in cross-sectional area toward its upper portion. As illustrated in Fig. 17, the first flow path portion 15 has a rectangular cross-section. However, the cross-section of the first flow path portion 15 may not necessarily be rectangular but may be, for example, semicircular, semielliptical, or semioval.

**[0124]** The first flow path portion 15 extends in the longitudinal direction of the first plate-shaped part 10 from the one end 151a of the main body portion toward the other end 151b. The first flow path portion 15 is closed at both ends in the direction of extension of the first flow path portion 15. In Fig. 16, the first flow path portion 15 has a side wall 15b having the shape of a trapezoid when viewed in the direction of stacking of the first plate-shaped part 10, the second plate-shaped part 20, and the third



plate-shaped part 30. The first flow path portion 15 has the shape of a quadrangular prism with the side wall 15b. The first flow path portion 15 is tapered in the longitudinal direction of the first plate-shaped part 10 from the lower end 15a2 near the refrigerant inlet 18 toward the upper end 15a1. The first flow path portion 15 may not necessarily have the shape of a quadrangular prism with the side wall 15b but may have another shape, such as a circular truncated cone or a polygonal truncated cone.

[Advantageous Effects of Heat Exchanger 100]

**[0125]** The main flow path 15a serving as the first flow path decreases in cross-sectional area from the lower end 15a2, which is one end communicating with the refrigerant inflow tube 60, toward the upper end 15a1, which is the other end. In the first direction (Z-axis direction), the main flow path 15a decreases in cross-sectional area toward the vertically upper portion of the main flow path 15a. This leads to increased flow rate of refrigerant through the main flow path 15a in the refrigerant distributor 150 of the heat exchanger 100. This helps to ensure that even if an operating condition of the air-conditioning apparatus causes the circulation rate of refrigerant to decrease, the refrigerant distributor 150 of the heat exchanger 100 allows refrigerant to reach the uppermost part of the main flow path 15a to thereby prevent or reduce maldistribution of refrigerant.

Embodiment 5

**[0126]** Fig. 19 is an exploded perspective view of the heat exchanger 100 according to Embodiment 5, conceptually illustrating the configuration of major components of the heat exchanger 100. Fig. 20 is a conceptual side view of the interior of the refrigerant distributor 150 illustrated in Fig. 19. Fig. 21 is a cross-sectional view of the heat exchanger 100 according to Embodiment 5, conceptually illustrating where the first and second flow paths of the refrigerant distributor 150 forming the heat exchanger 100 communicate with each other. Components identical in function and operation to the components described above with reference to Embodiment 1 are designated by the same reference signs and not described in further detail below. In Embodiments 1 to 4, the refrigerant distributor 150 is a stack of multiple parts such as the first to fifth plate-shaped parts 10 to 50. By contrast, the body 151 of the refrigerant distributor 150 according to Embodiment 5 is a tubular part.

**[0127]** The body 151 of the refrigerant distributor 150 extends in the first direction (Z-axis direction), and connects with one end of each of the heat transfer tubes 70 to distribute refrigerant to the heat transfer tubes 70.

**[0128]** The body 151 of the refrigerant distributor 150 has a tubular portion 90 extending in the first direction (Z-axis direction) in which the heat transfer tubes 70 are arranged. The body 151 of the refrigerant distributor 150 has a wall 91 in a hollow portion 95 of the tubular portion

90. The wall 91 divides the main flow path 15a and the sub-flow path 25 from each other in the third direction, and has an inlet portion 92a and an outlet portion 92b, which are through-holes and located at opposite ends of the wall 91 in the first direction. Further, the body 151 of the refrigerant distributor 150 includes a lid 94 for closing both ends of the tubular portion 90.

**[0129]** The tubular portion 90 is in the form of a hollow circular cylinder extending in the direction of arrangement of the heat transfer tubes 70. However, the tubular portion 90 may not necessarily be in the form of a circular cylinder but may be in any tubular form. For example, the tubular portion 90 may be in the form of a cuboid box. In Fig. 19, the tubular portion 90 has a first tubular portion 90a that connects with the refrigerant inflow tube 60, and a second tubular portion 90b that connects with the heat transfer tubes 70. The first tubular portion 90a and the second tubular portion 90b each have the shape of a semicircular arc when viewed in cross-section perpendicular to the first direction (Z-axis direction). The first tubular portion 90a and the second tubular portion 90b of the tubular portion 90 may not be separate components. Alternatively, the first tubular portion 90a and the second tubular portion 90b may be integral with each other.

**[0130]** The wall 91 is in the form of a strip elongated in one direction. The wall 91 is a plate-shaped portion extending in the direction of arrangement of the heat transfer tubes 70. The longitudinal direction of the wall 91 aligns with the first direction (Z-axis direction) in which the heat transfer tubes 70 are arranged. The lateral direction of the wall 91 aligns with the second direction (X-axis direction) in which the tube paths of the heat transfer tubes 70 extend. The direction of plate thickness of the wall 91 aligns with the long-axis direction of each heat transfer tube 70. The wall 91 defines a plate plane extending in the first direction (Z-axis direction) and the second direction (X-axis direction).

**[0131]** The wall 91 has the outlet portion 92b at one end 91b, which is an end connected with the refrigerant inflow tube 60. The wall 91 has the inlet portion 92a at the other end 91a. The inlet portion 92a and the outlet portion 92b are through-holes extending through the wall 91 in the direction of plate thickness of the wall 91. In the body 151, the inlet portion 92a and the outlet portion 92b each define a flow path that extends in the third direction.

**[0132]** The wall 91 has multiple insertion holes 93 each configured to receive one end of the corresponding one of the heat transfer tubes 70 inserted into the insertion hole 93. Each of the insertion holes 93 is a through-hole extending through the wall 91 in the direction of plate thickness of the wall 91. Each of the insertion holes 93 is a cutout extending from an edge 91e, which extends in the first direction (Z-axis direction), toward an edge 91d opposite to the edge 91e.

**[0133]** The insertion holes 93 are arranged in parallel in the up-down direction along the length of the wall 91. The insertion holes 93 are provided independently of each other in one-to-one correspondence to the heat

transfer tubes 70. Each insertion hole 93 defines an opening with a flattened shape that conforms to the outer circumferential shape of the corresponding heat transfer tube 70. The entire circumference of the opening edge of each insertion hole 93 is joined by brazing to the outer circumferential surface of the corresponding heat transfer tube 70. By joining the heat transfer tubes 70 to the wall 91, the heat transfer tubes 70 are connected to the wall 91 such that the heat transfer tubes 70 communicate with the main flow path 15a serving as the first flow path, and the sub-flow path 25 serving as the second flow path.

**[0134]** The lid 94 closes both ends of the tubular portion 90 in the direction in which the tubular portion 90 extends. The lid 94 may be any part for closing both ends of the tubular portion 90 in the direction in which the tubular portion 90 extends. The lid 94 may be a plate-shaped part, or may be a part that overlies both ends of the tubular portion 90.

**[0135]** The hollow portion 95 inside the tubular portion 90 is defined by the tubular portion 90, and the lid 94 that closes both ends of the tubular portion 90. As illustrated in Fig. 21, the hollow portion 95 inside the tubular portion 90 is divided by the wall 91 into two spaces, a first space S1 and a second space S2. The first space S1 and the second space S2 communicate with each other via the inlet portion 92a and the outlet portion 92b.

**[0136]** In the body 151 of the refrigerant distributor 150, the first space S1 defines the main flow path 15a. The main flow path 15a is a flow path through which refrigerant flows from the one end 151a of the body 151, which is an end connected with the refrigerant inflow tube 60, to the other end 151b. With the first direction (Z-axis direction) defined as the up-down direction, refrigerant flows upward in the main flow path 15a. The main flow path 15a serving as the first flow path is formed so as to extend in the first direction (Z-axis direction), communicates with the heat transfer tubes 70, and is connected, at the lower end 15a2 in the first direction, with the refrigerant inflow tube 60 configured to cause refrigerant to flow into the refrigerant distributor 150.

**[0137]** In the body 151 of the refrigerant distributor 150, the second space S2, the inlet portion 92a, and the outlet portion 92b define the sub-flow path 25. The sub-flow path 25 is a flow path through which refrigerant flows from the other end 151b to the one end 151a of the body 151, which is an end connected with the refrigerant inflow tube 60. With the first direction (Z-axis direction) defined as the up-down direction, refrigerant flows downward in the sub-flow path 25. The sub-flow path 25 serving as the second flow path extends in the first direction, with the inlet portion 92a and the outlet portion 92b at opposite ends being connected with the main flow path 15a serving as the first flow path. The sub-flow path 25 serving as the second flow path is located in the third direction relative to the main flow path 15a serving as the first flow path. That is, the main flow path 15a and the sub-flow path 25 are located upstream and downstream in the direction of airflow created by the outdoor fan 108 or the

indoor fan 109 illustrated in Fig. 1.

**[0138]** The body 151 of the refrigerant distributor 150 includes, in its inside, the main flow path 15a serving as the first flow path, and the sub-flow path 25 serving as the second flow path, which are flow paths through which refrigerant flows. In the body 151 of the refrigerant distributor 150, the main flow path 15a and the sub-flow path 25 define a flow path in which refrigerant circulates.

**[0139]** Fig. 22 is a cross-sectional view of the heat exchanger according to Embodiment 5, conceptually illustrating where the first and second flow paths of a modification of the refrigerant distributor forming the heat exchanger communicate with each other. The tubular portion 90 may not necessarily be in the form of a circular cylinder illustrated in Fig. 21. The tubular portion 90 may be in any tubular form. For example, the tubular portion 90 may be in the form of a semicircular cylinder illustrated in Fig. 22.

**[0140]** Fig. 23 conceptually illustrates how refrigerant flows within the refrigerant distributor 150 forming the heat exchanger 100 according to Embodiment 5. As with Embodiment 1, refrigerant that accumulates in an upper portion of the main flow path 15a flows into the inlet portion 92a defined in the second plate-shaped part 20 and communicating with the upper end 15a1 of the main flow path 15a. At this time, as represented by the arrow OF, the refrigerant flows in the third direction from the main flow path 15a serving as the first flow path toward the sub-flow path 25 serving as the second flow path. Then, as represented by the arrow DF, the refrigerant entering through the inlet portion 92a of the sub-flow path 25 flows downward in the direction of gravity in the sub-flow path 25 defined in the second plate-shaped part 20.

**[0141]** Upon reaching the lower end of the sub-flow path 25, the refrigerant exits the sub-flow path 25 into the main flow path 15a through the outlet portion 92b communicating with the lower end 15a2 of the main flow path 15a. At this time, as represented by the arrow IF, the refrigerant flows in the third direction from the sub-flow path 25 serving as the second flow path toward the main flow path 15a serving as the first flow path. After exiting through the outlet portion 92b into the main flow path 15a, the exiting refrigerant, together with the refrigerant flowing into the body 151 through the refrigerant inflow tube 60, travels vertically upward in the main flow path 15a, and is distributed to each heat transfer tube 70.

[Advantageous Effects of Heat Exchanger 100]

**[0142]** The refrigerant distributor 150 includes the tubular portion 90, the lid 94, and the wall 91. The wall 91 divides the main flow path 15a serving as the first flow path, and the sub-flow path 25 serving as the second flow path from each other in the third direction. The wall 91 has the inlet portion 92a and the outlet portion 92b, which are through-holes and located at opposite ends of the wall 91 in the first direction. The heat transfer tubes 70 are connected to the wall 91 so as to communicate

with the main flow path 15a serving as the first flow path and the sub-flow path 25 serving as the second flow path. As a result, even if the body 151 is a tubular part such as a circular tube, the above-mentioned configuration of the heat exchanger 100 helps to prevent or reduce an increase in the size of the refrigerant distributor 150 in the second direction in which refrigerant is circulated, and allows the heat exchanger 100 to be enlarged, within a range of structural constraints, in the second direction in which the tube paths of the heat transfer tubes 70 extend. Therefore, the heat exchanger 100 allows for increased heat transfer surface area of the heat transfer tubes 70, and also allows the refrigerant distributor 150 to be made compact without an increase in the size of the refrigerant distributor 150 in the direction in which the tube paths of the heat transfer tubes 70 extend.

**[0143]** The refrigeration cycle apparatus 200 includes the heat exchanger 100 according to any one of Embodiments 1 to 5. Accordingly, the refrigeration cycle apparatus 200 provides an effect similar to any one of Embodiments 1 to 5.

**[0144]** Embodiments 1 to 5 mentioned above can be practiced in combination with each other. The configurations described above with reference to the embodiments are intended to be illustrative only. These configurations can be combined with other known techniques, or can be partially omitted or changed without departing from the scope of the present disclosure. For example, the refrigerant distributor 150 or other components according to Embodiments 1 to 5 may be of a longitudinally mounted type with the body 151 extending in the vertical direction, or may be of a transversely mounted type with the body 151 extending in the horizontal direction. The refrigerant distributor 150 or other components according to Embodiment 1 to 5 may be designed such that the body 151 is inclined relative to the vertical direction. Reference Signs List

**[0145]** 10: first plate-shaped part, 11: flat plate portion, 11a: flat plate portion, 11b: flat plate portion, 15: first flow path portion, 15a: main flow path, 15a1: upper end, 15a2: lower end, 15b: side wall, 18: refrigerant inlet, 20: second plate-shaped part, 24: blocking portion, 25: sub-flow path, 25a: middle portion, 25a1: end, 25a2: end, 25b: inlet portion, 25c: outlet portion, 25c1: outlet portion, 26: distribution hole, 30: third plate-shaped part, 31: insertion hole, 34: flat plate portion, 40: fourth plate-shaped part, 44: blocking portion, 45: communication hole, 46: second distribution hole, 50: fifth plate-shaped part, 51: third distribution hole, 53: blocking portion, 60: refrigerant inflow tube, 70: heat transfer tube, 70a: first side end, 70b: second side end, 70c: flat surface, 70d: flat surface, 71: gap, 72: refrigerant passage, 75: heat transfer fin, 90: tubular portion, 90a: first tubular portion, 90b: second tubular portion, 91: wall, 91a: end, 91b: end, 91d: edge, 91e: edge, 92a: inlet portion, 92b: outlet portion, 93: insertion hole, 94: lid, 95: hollow portion, 100: heat exchanger, 101: compressor, 102: flow switching device, 103: indoor heat exchanger, 104: pressure reducing device, 105: outdoor

heat exchanger, 106: outdoor unit, 107: indoor unit, 108: outdoor fan, 109: indoor fan, 110: refrigerant circuit, 111: extension pipe, 112: extension pipe, 115: flow path portion, 150: refrigerant distributor, 151: body, 151a: end, 151b: end, 200: refrigeration cycle apparatus.

## Claims

### 1. A heat exchanger comprising:

a plurality of heat transfer tubes arranged at intervals in a first direction, and configured to circulate refrigerant in a second direction intersecting the first direction; and  
a refrigerant distributor extending in the first direction and is connected to one end of each of the plurality of heat transfer tubes, the refrigerant distributor being configured to distribute the refrigerant to the plurality of heat transfer tubes, wherein  
the refrigerant distributor includes, in its inside, a first flow path and a second flow path through which the refrigerant flows,  
the first flow path is formed so as to extend in the first direction, communicates with the plurality of heat transfer tubes, and is connected with an inflow tube configured to cause the refrigerant to flow into the refrigerant distributor, and  
the second flow path is formed so as to extend in the first direction, with opposite ends thereof being connected with the first flow path, and is formed so as to be positioned in a third direction relative to the first flow path, when a direction intersecting a plane parallel to the first direction and to the second direction is defined as the third direction.

### 2. The heat exchanger of claim 1,

wherein  
the refrigerant distributor includes

a first plate-shaped part including the first flow path,  
a second plate-shaped part including a distribution hole and the second flow path, the distribution hole being a through-hole located between the plurality of heat transfer tubes and the first flow path, and  
a third plate-shaped part including an insertion hole, the insertion hole being a through-hole into which each of the plurality of heat transfer tubes is inserted,

the first plate-shaped part, the second plate-shaped part, and the third plate-shaped part are stacked together, and

- in a direction of stacking of the first plate-shaped part, the second plate-shaped part, and the third plate-shaped part, the first flow path and the opposite ends overlap each other, and the first flow path, the distribution hole, and the insertion hole overlap each other. 5
3. The heat exchanger of claim 2, wherein a plurality of the distribution holes are provided in the first direction. 10
4. The heat exchanger of claim 2 or 3, wherein the second flow path is disposed beside both sides of the distribution hole in the third direction. 15
5. The heat exchanger of any one of claims 2 to 4, wherein the refrigerant distributor includes 20
- a fourth plate-shaped part disposed between the first plate-shaped part and the second plate-shaped part, and a fifth plate-shaped part disposed between the second plate-shaped part and the third plate-shaped part, 25
- the fourth plate-shaped part includes 30
- a communication hole, the communication hole being a through-hole located between the first flow path and the opposite ends, and 35
- a second distribution hole, the second distribution hole being a through-hole located between the first flow path and the distribution hole, and 40
- the fifth plate-shaped part includes a third distribution hole, the third distribution hole being a through-hole located between the distribution hole and the insertion hole. 45
6. The heat exchanger of any one of claims 2 to 5, wherein the opposite ends include 50
- an inlet portion into which the refrigerant flows from the first flow path, and an outlet portion from which the refrigerant flows out into the first flow path, and 55
- the inlet portion and the outlet portion are formed so as to extend in the third direction.
7. The heat exchanger of any one of claims 2 to 5, wherein the opposite ends include
- an inlet portion into which the refrigerant flows from the first flow path, an outlet portion from which the refrigerant flows out into the first flow path, and
- the outlet portion is inclined relative to the first direction and the third direction such that a direction of flow of the refrigerant exiting the outlet portion has a vector component of a direction of flow of the refrigerant exiting the refrigerant inflow tube.
8. The heat exchanger of any one of claims 1 to 7, wherein the first flow path decreases in cross-sectional area from one end toward an other end, the one end being an end connected with the inflow tube.
9. The heat exchanger of claim 1, wherein the refrigerant distributor includes
- a tubular portion extending in the first direction, a lid that closes both ends of the tubular portion, and a wall that, in a hollow portion of the tubular portion, divides the first flow path and the second flow path from each other in the third direction, and has an inlet portion and an outlet portion, the inlet portion and the outlet portion being through-holes located at opposite ends of the wall in the first direction, and
- the plurality of heat transfer tubes are connected to the wall so as to communicate with the first flow path and the second flow path.
10. A refrigeration cycle apparatus comprising the heat exchanger of any one of claims 1 to 9.

FIG. 1

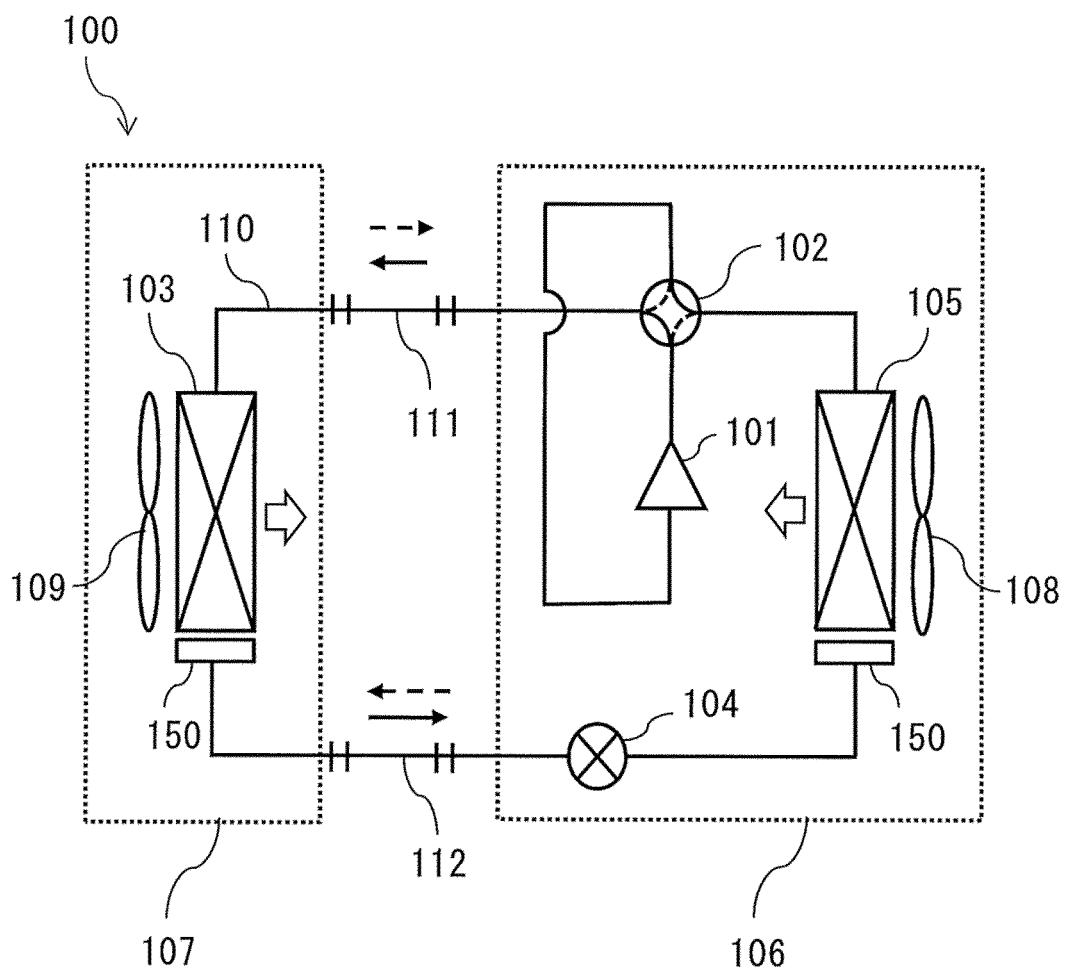


FIG. 2

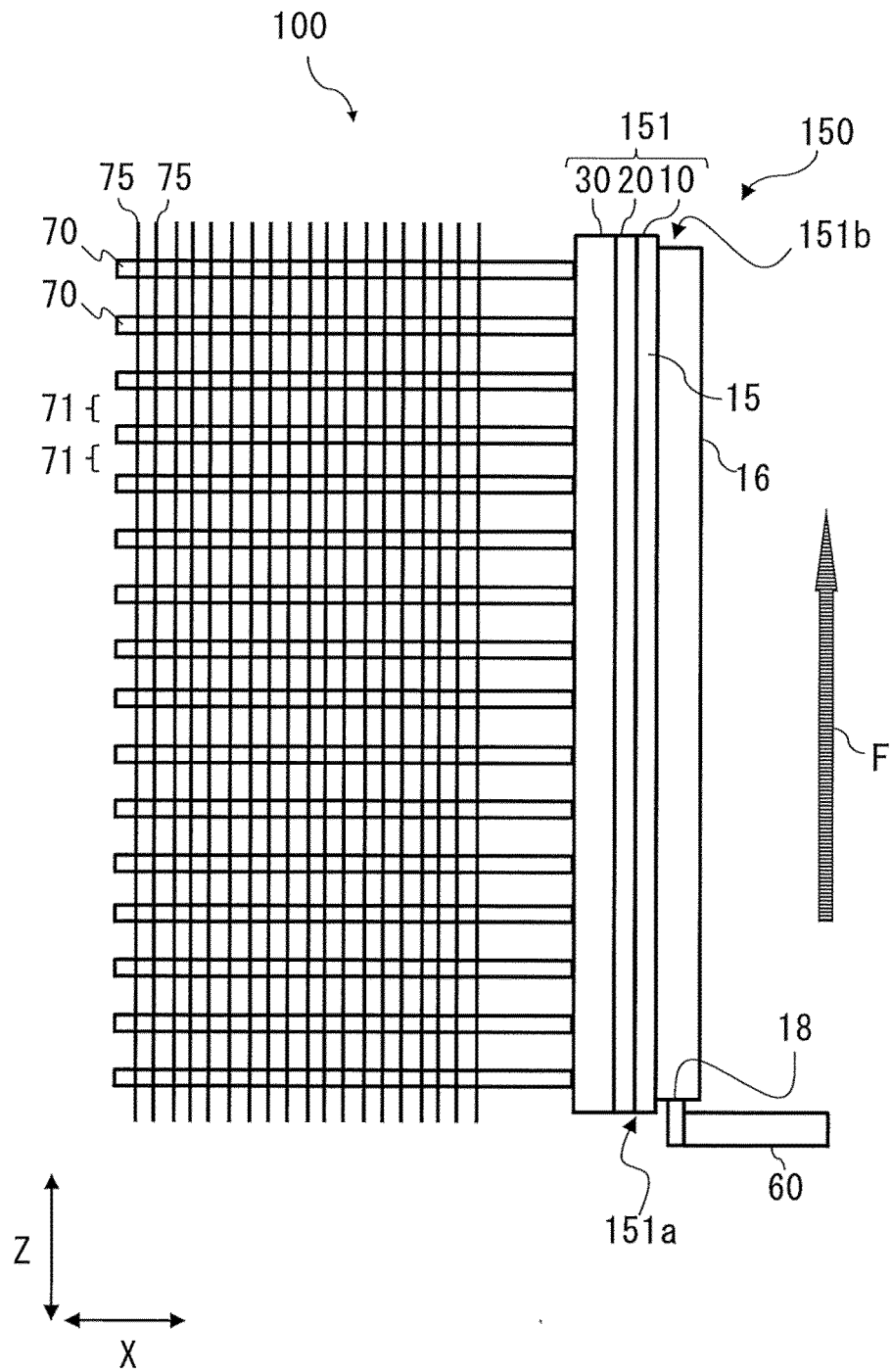


FIG. 3

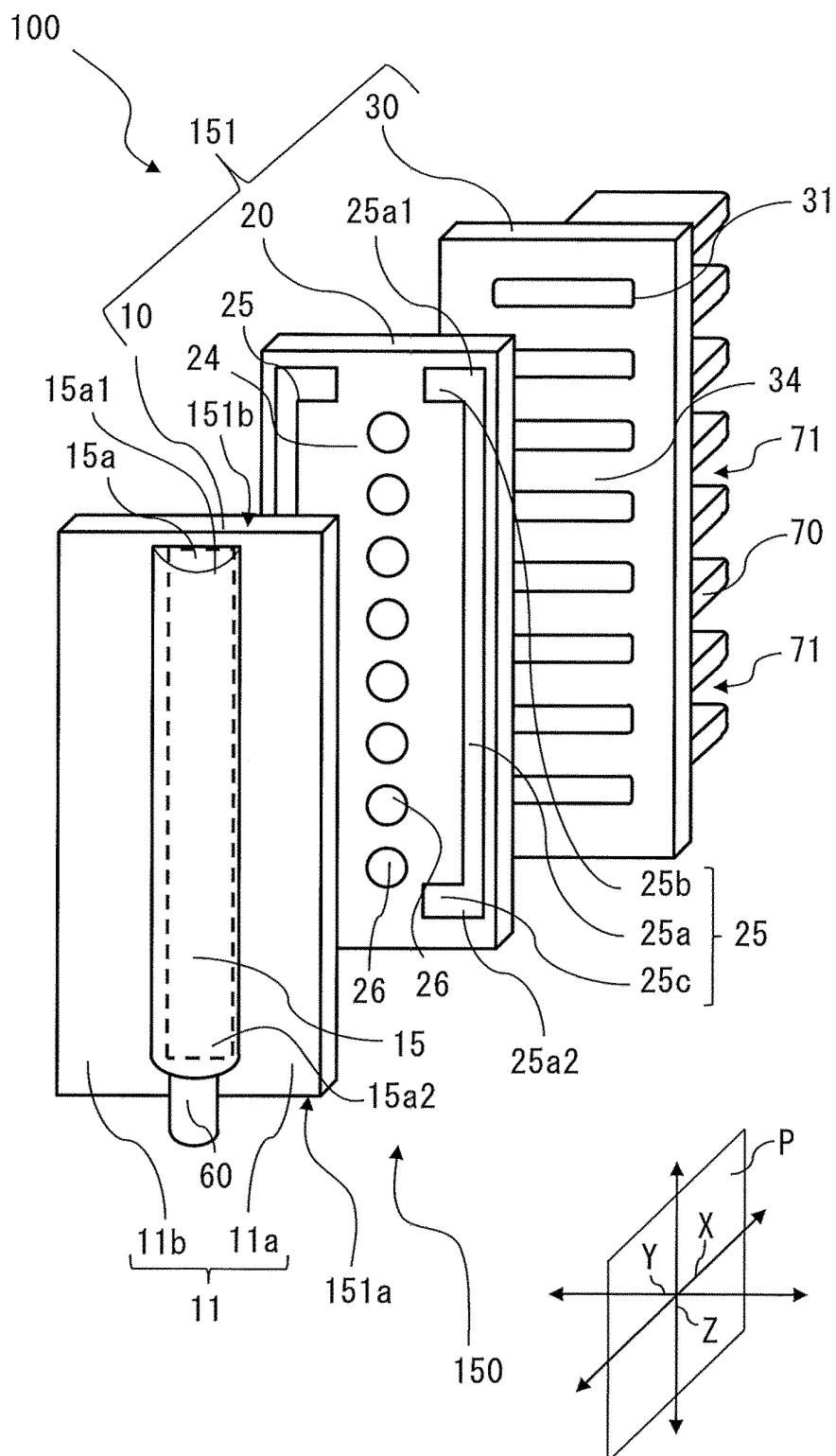


FIG. 4

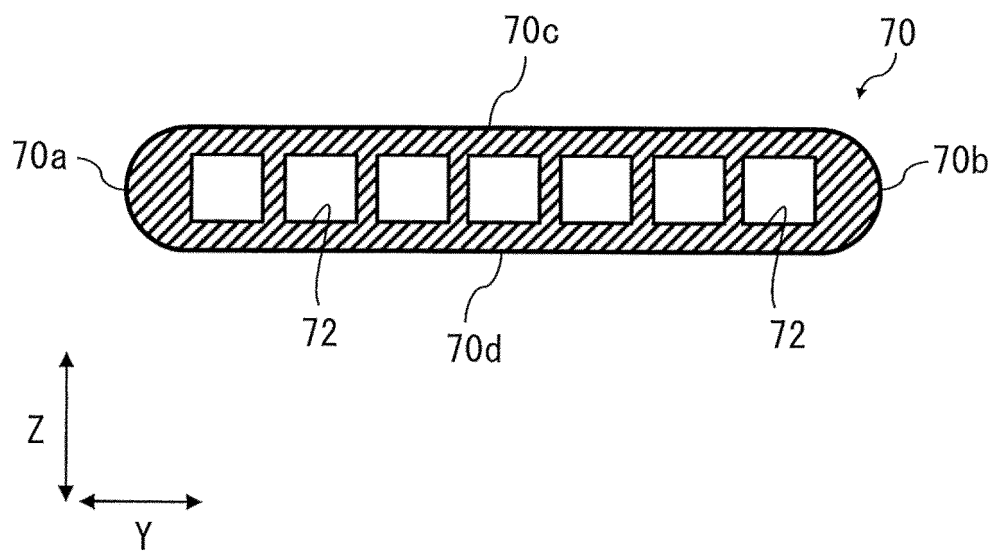




FIG. 5

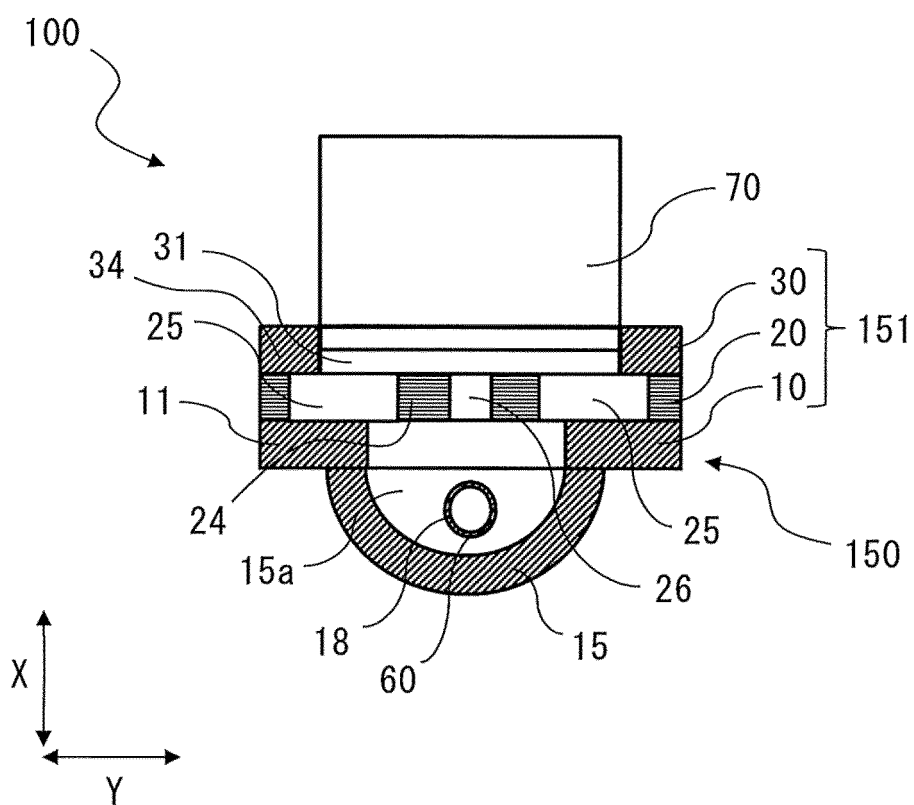


FIG. 6

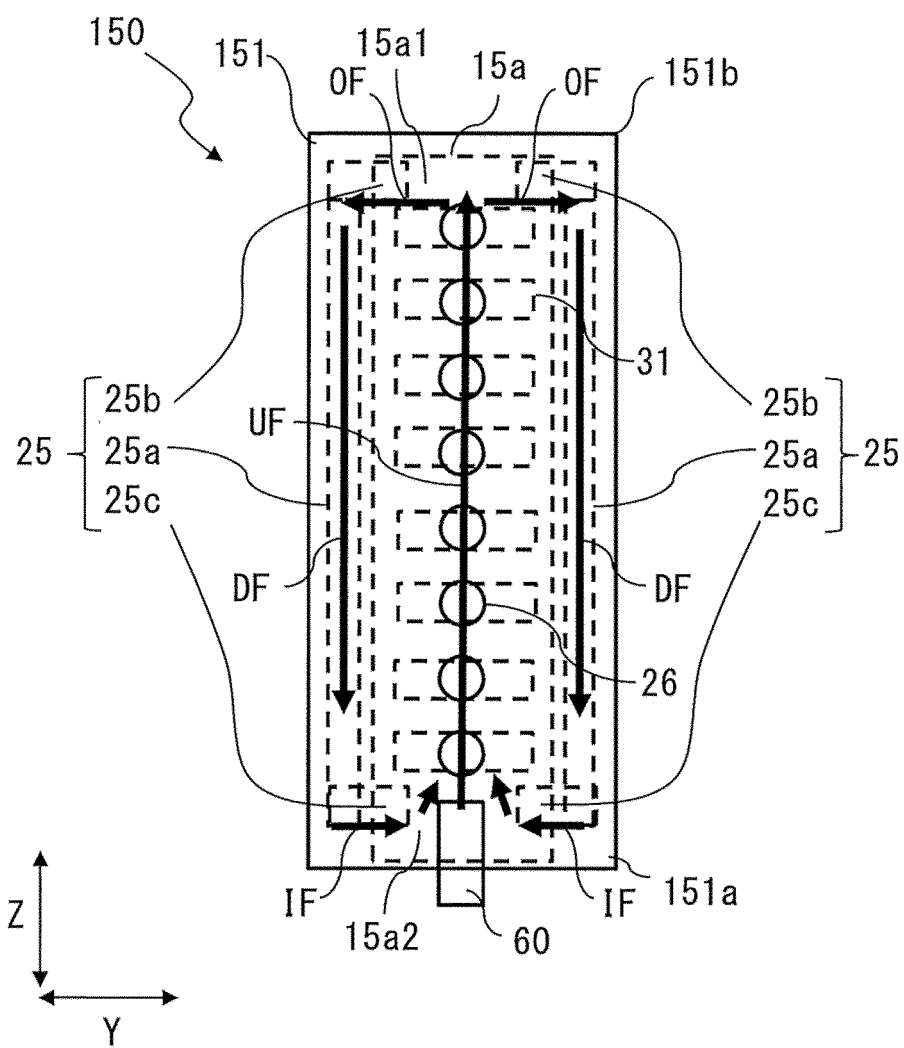


FIG. 7

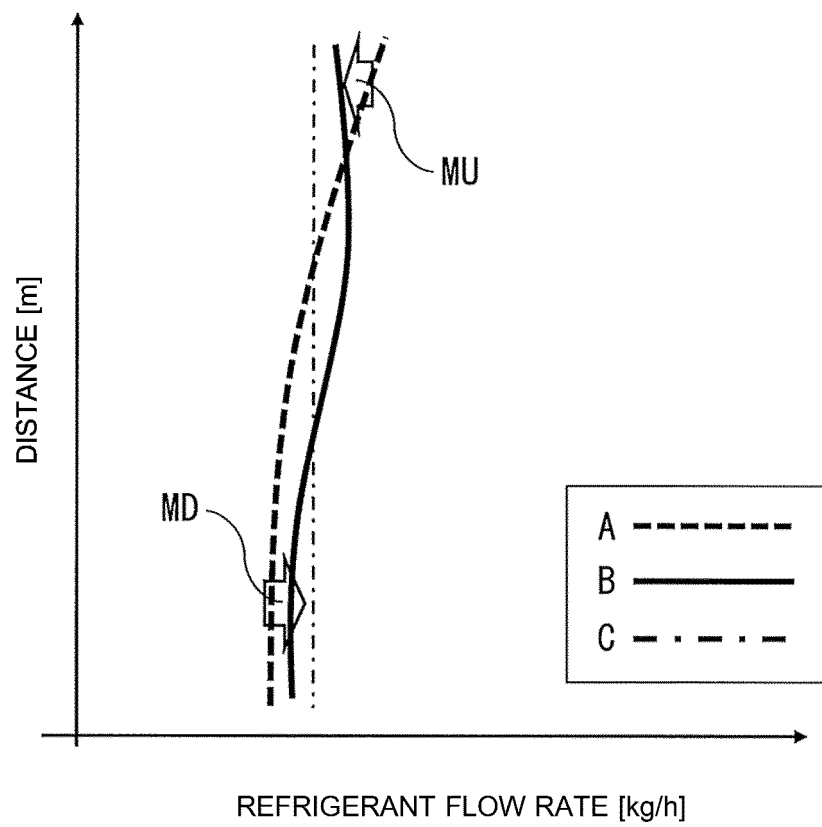


FIG. 8

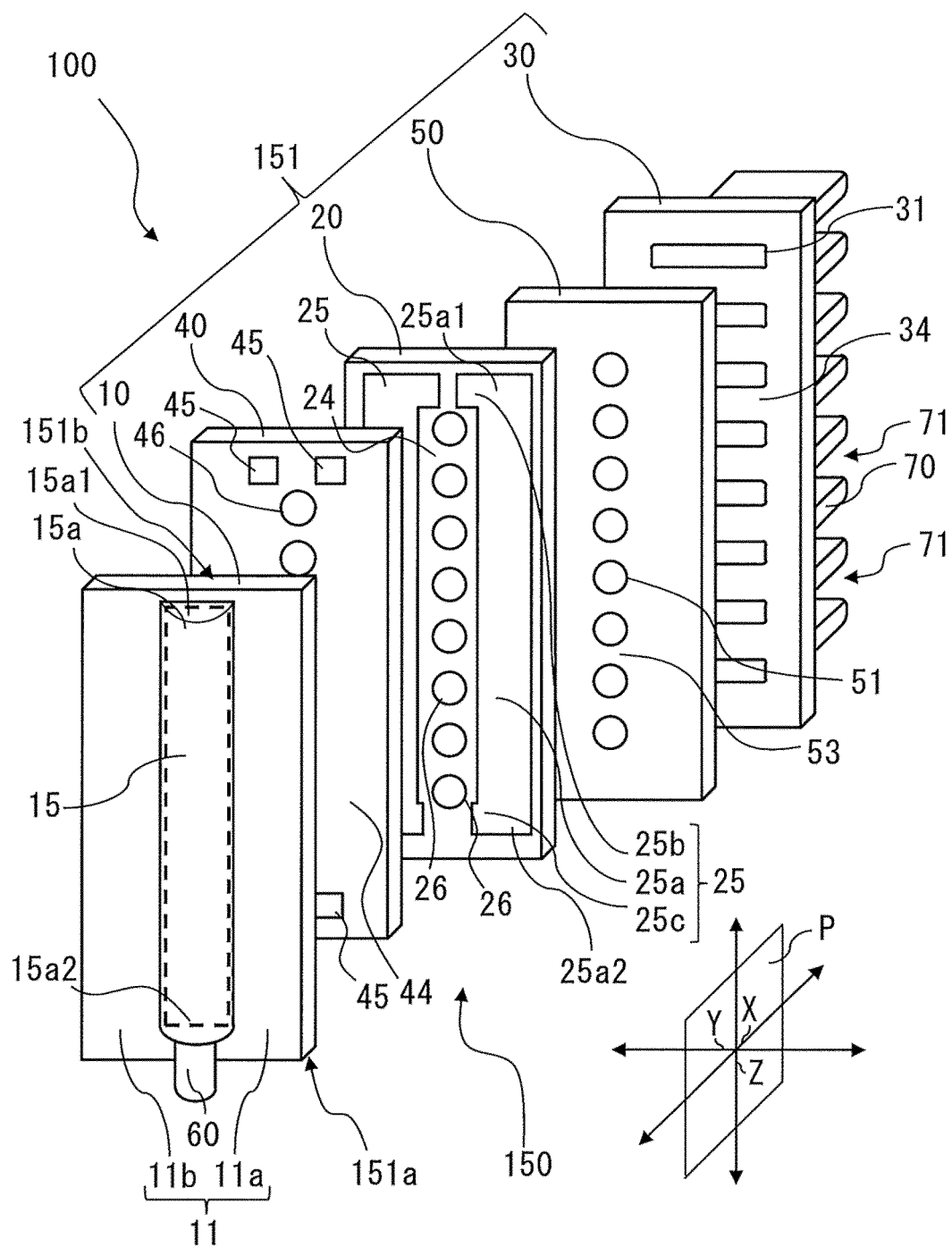


FIG. 9

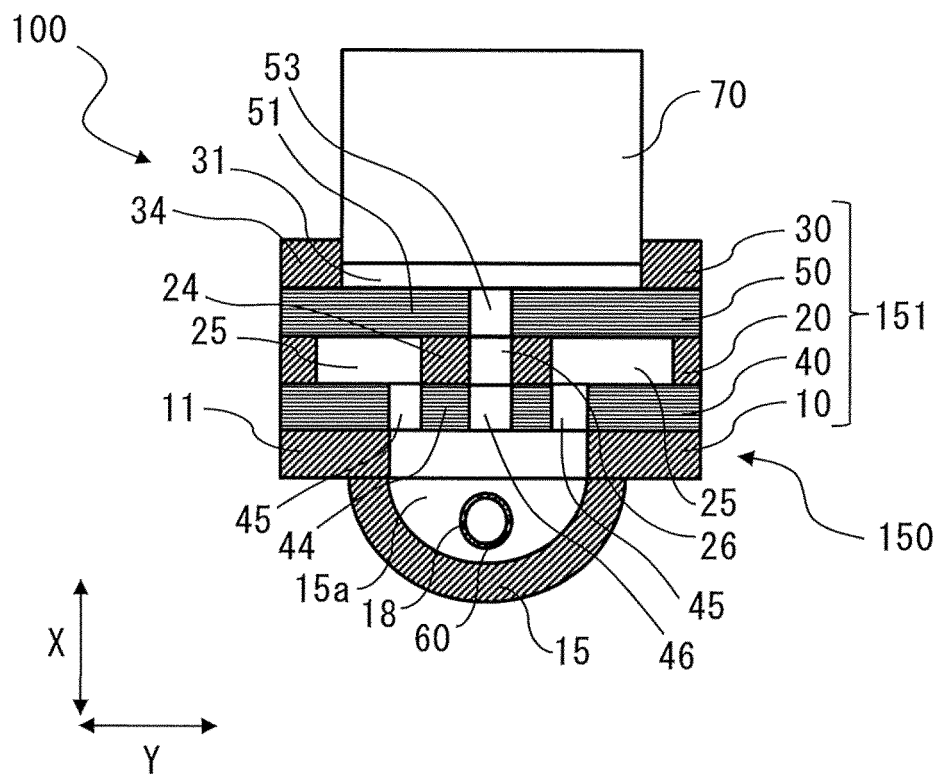


FIG. 10

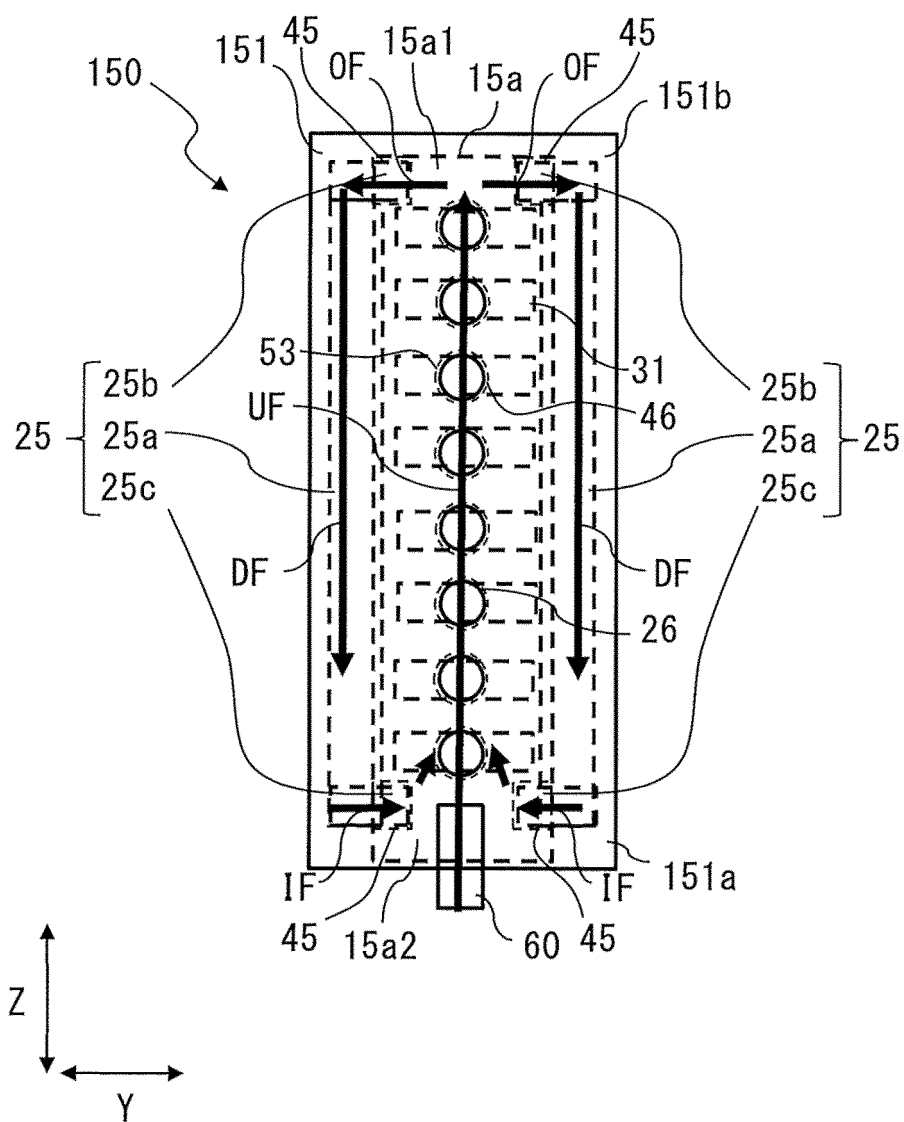


FIG. 11

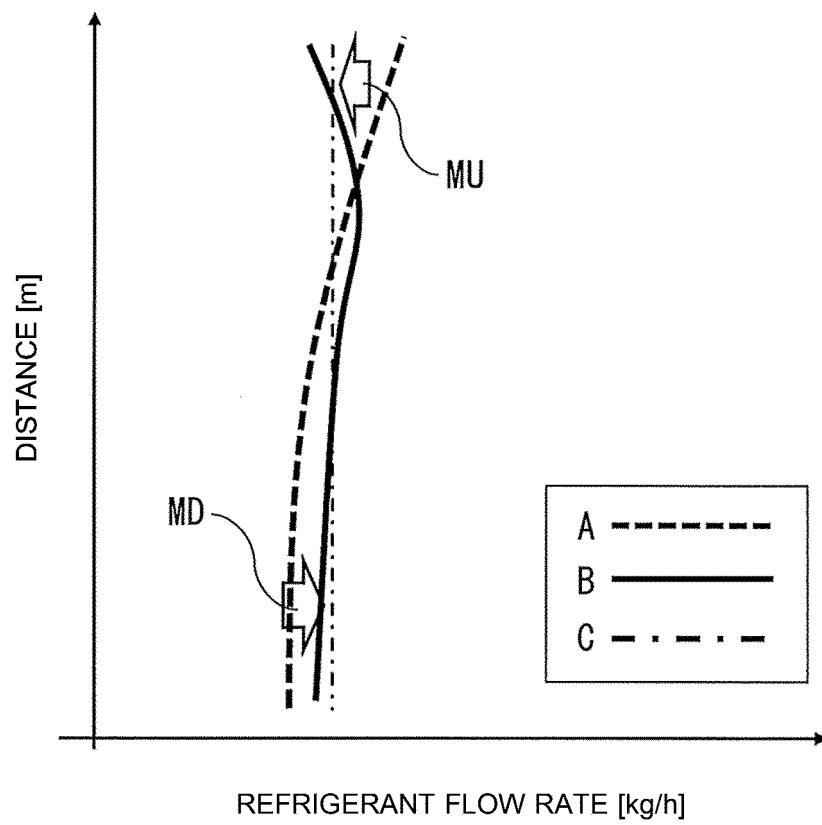


FIG. 12

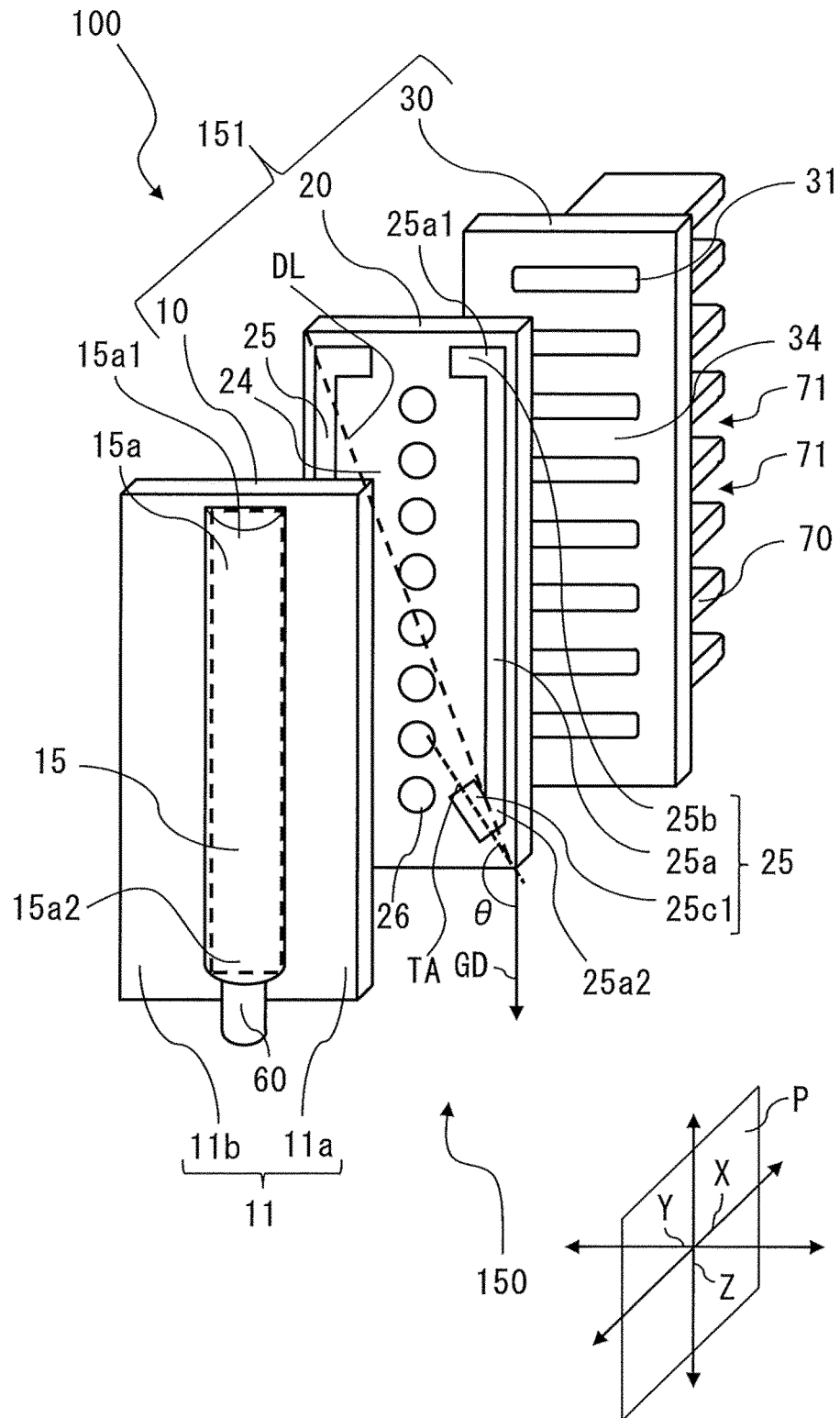




FIG. 13

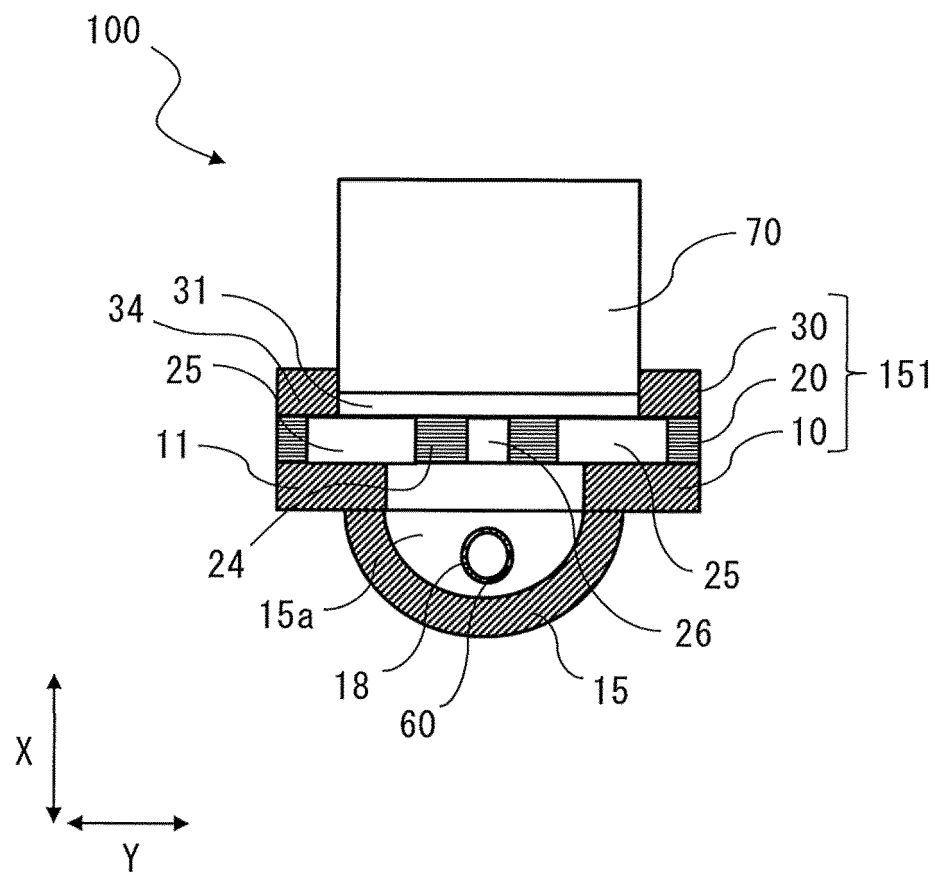


FIG. 14

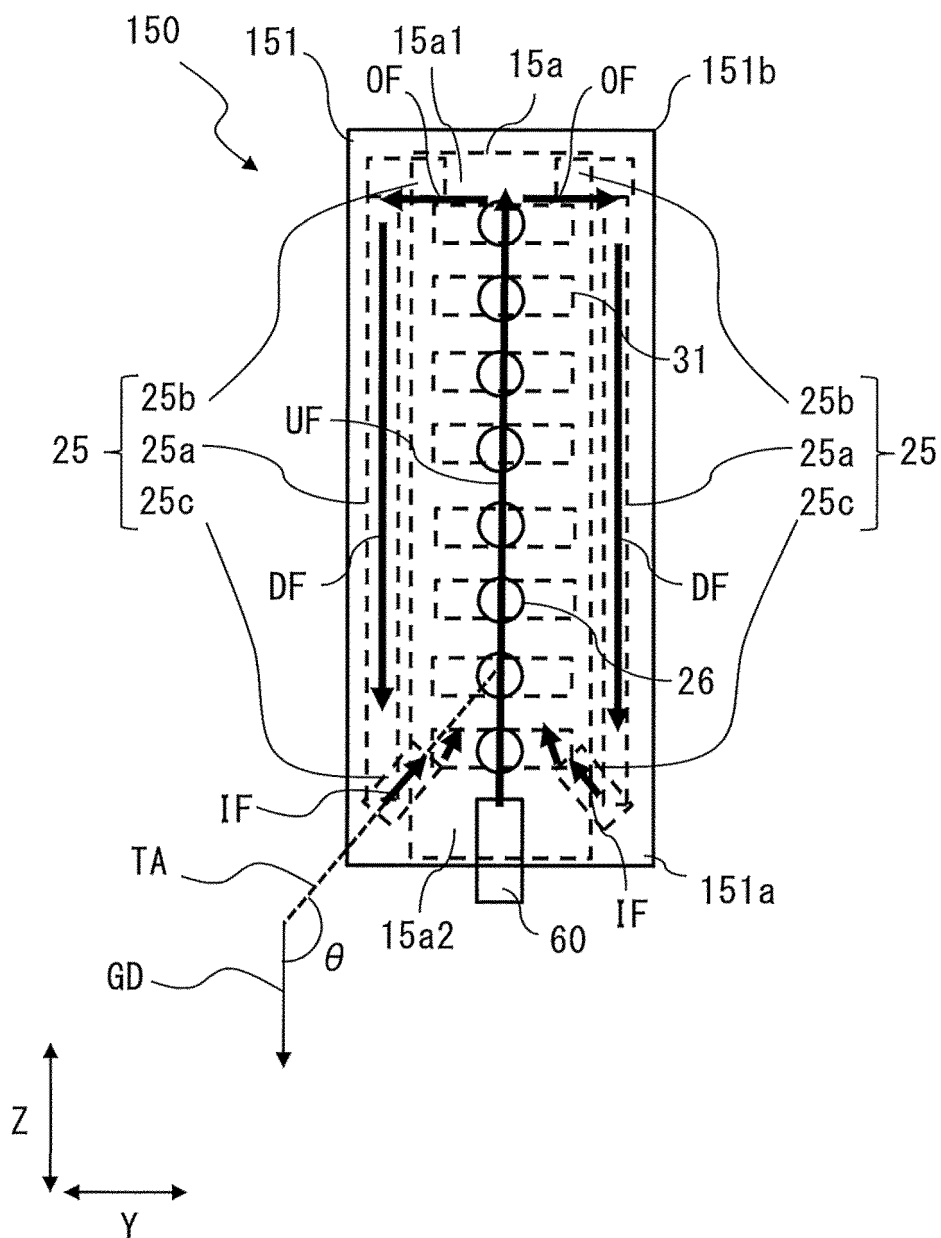


FIG. 15

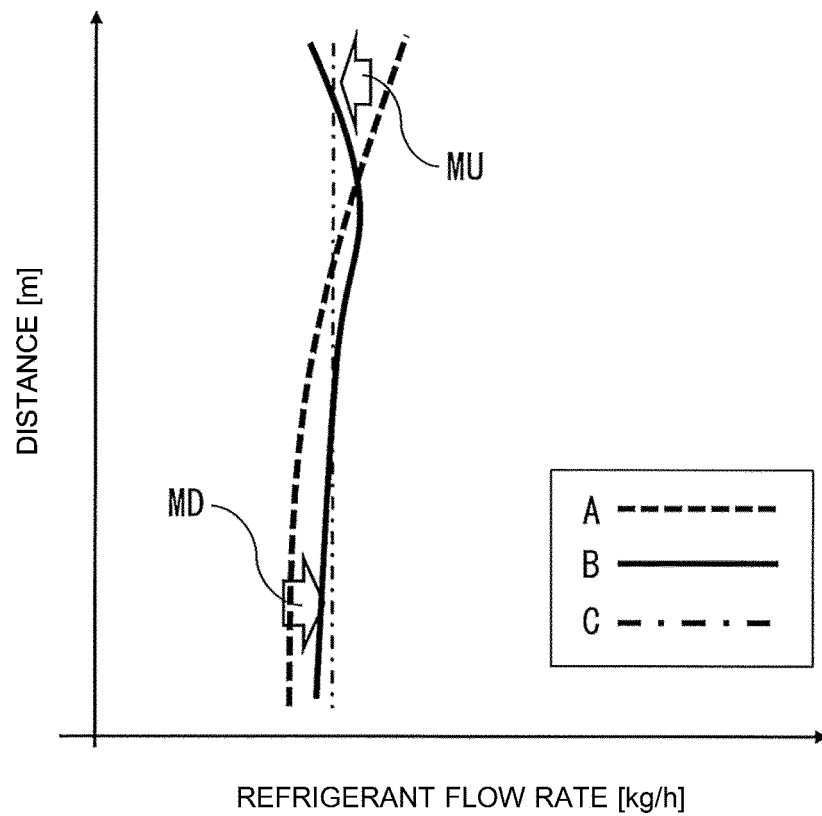


FIG. 16

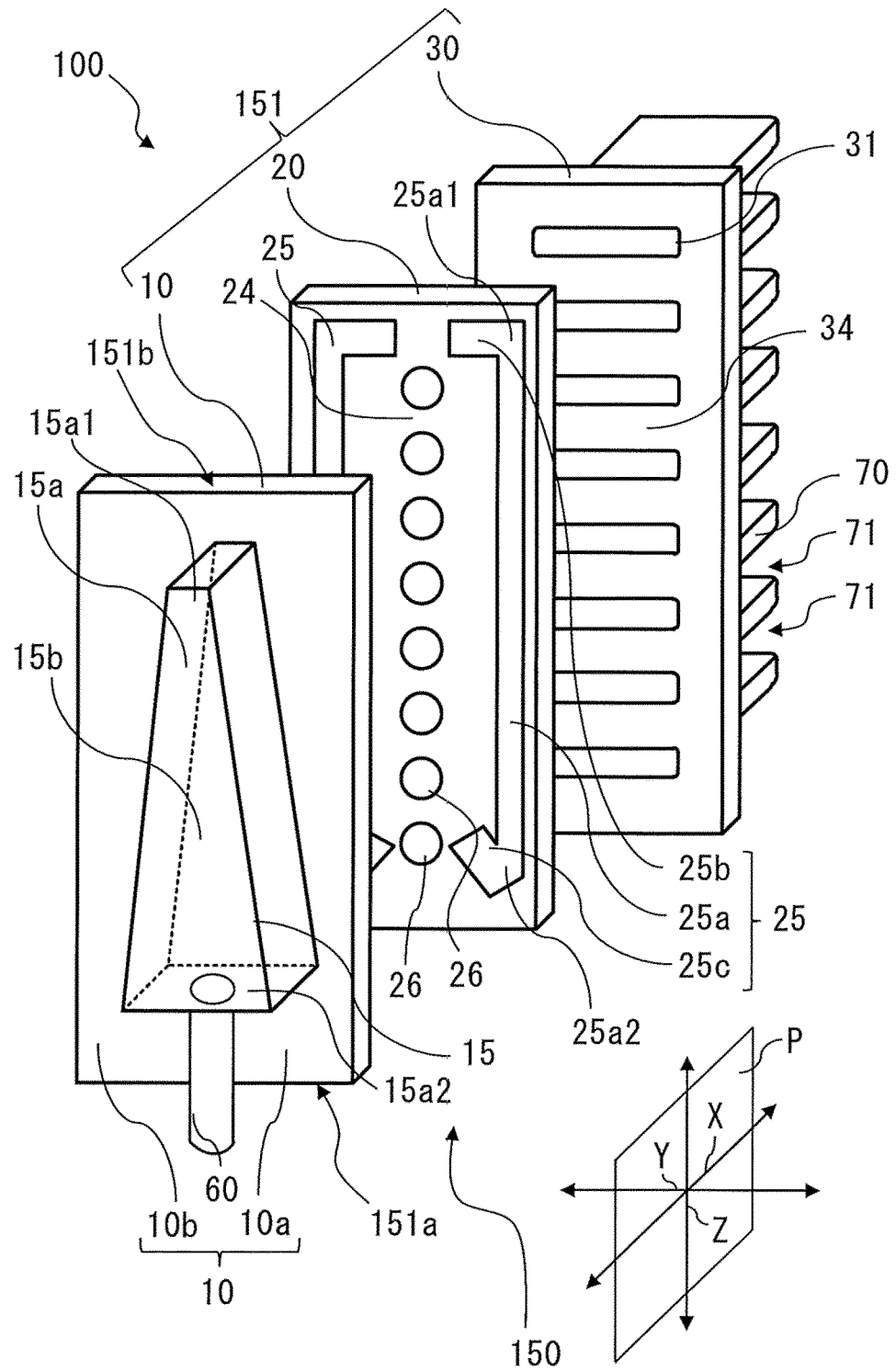


FIG. 17

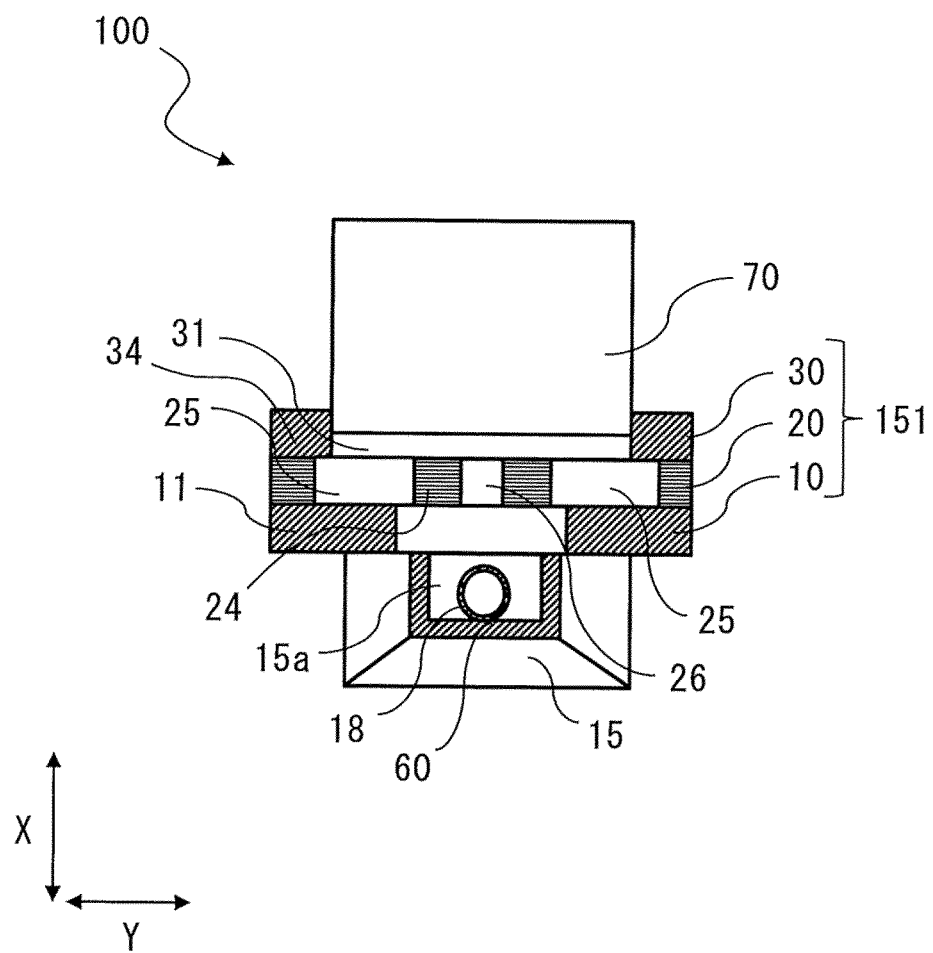


FIG. 18

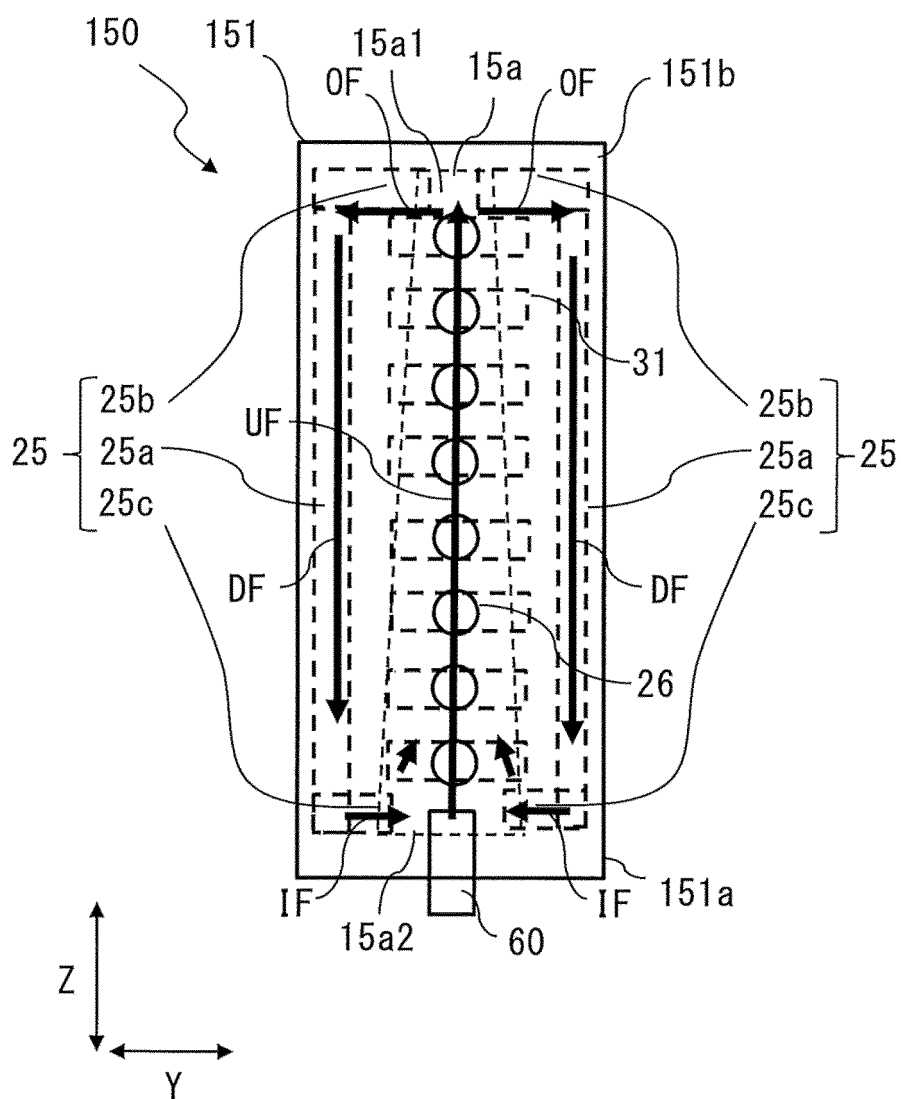


FIG. 19

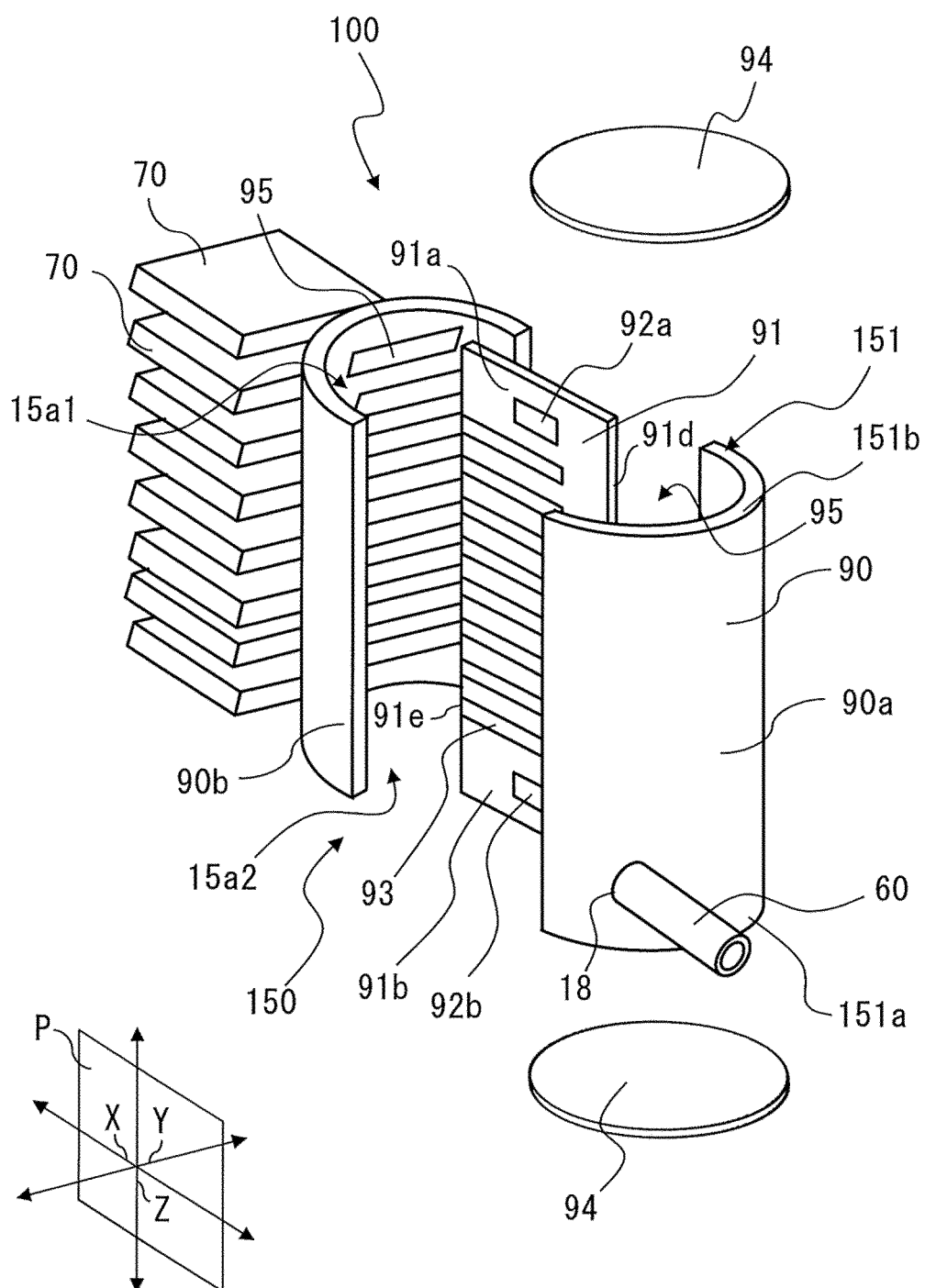


FIG. 20

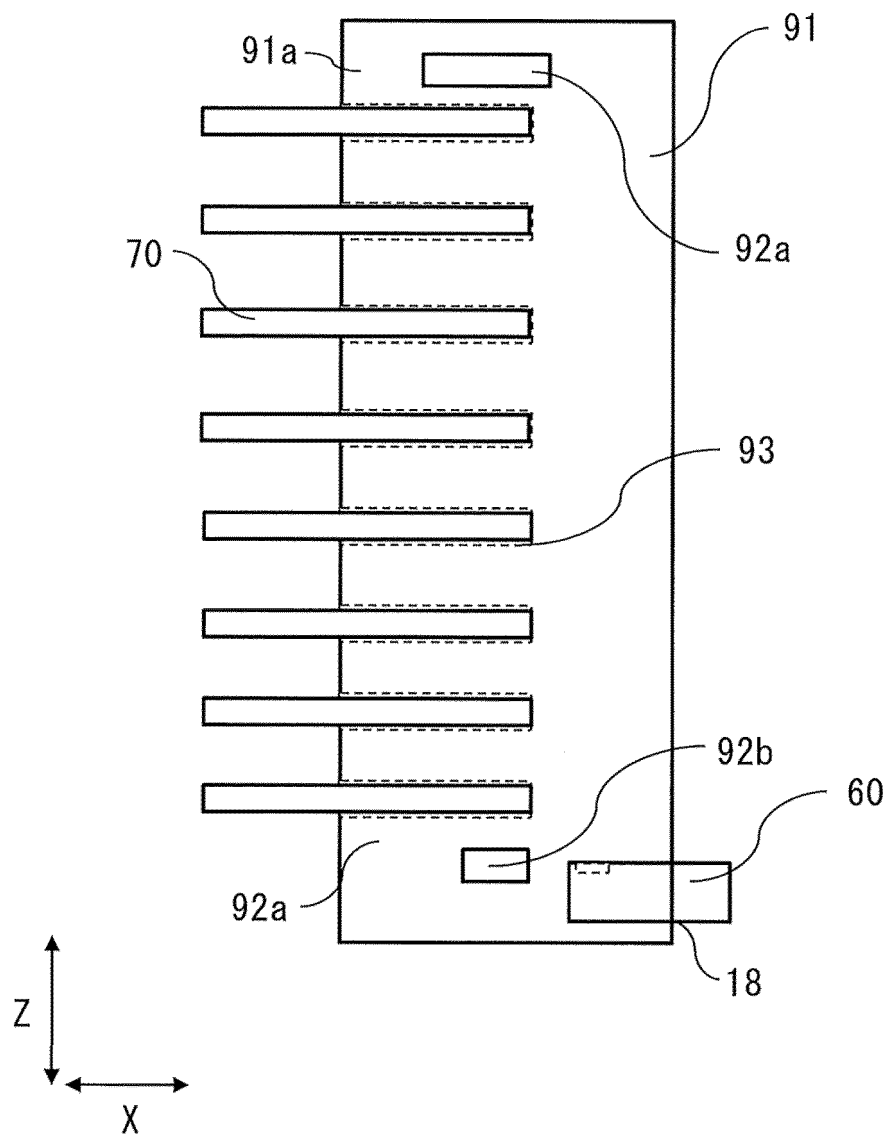




FIG. 21

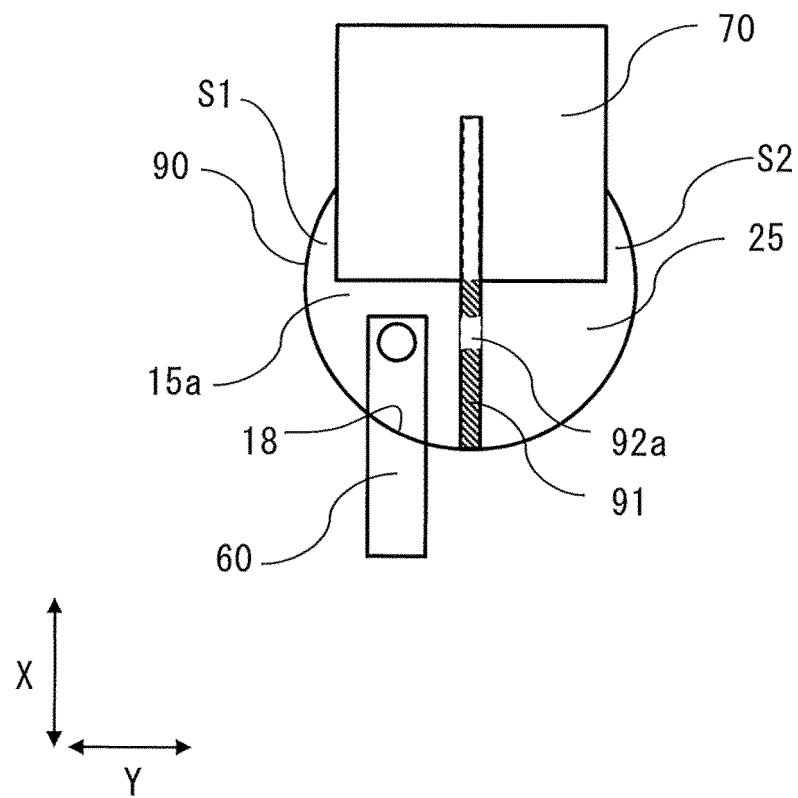


FIG. 22

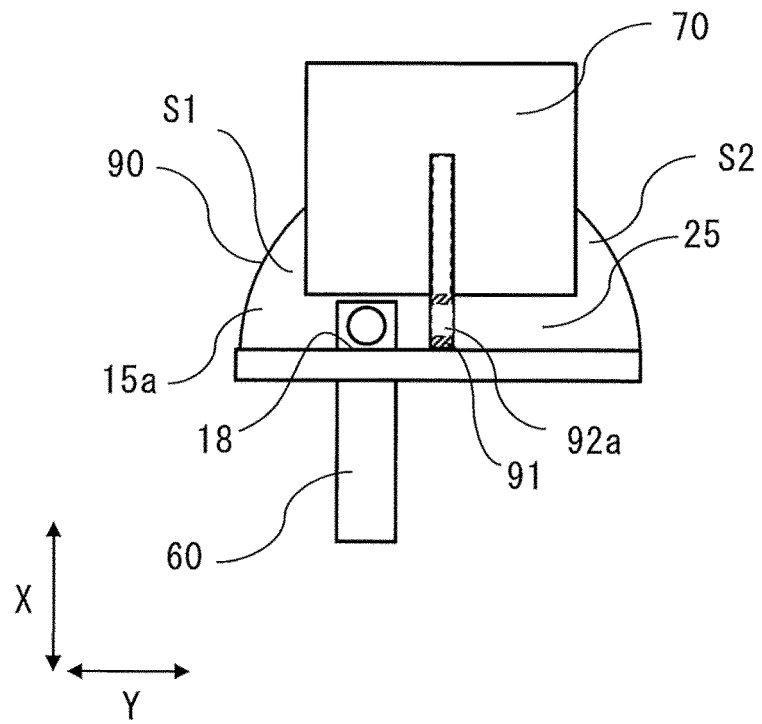
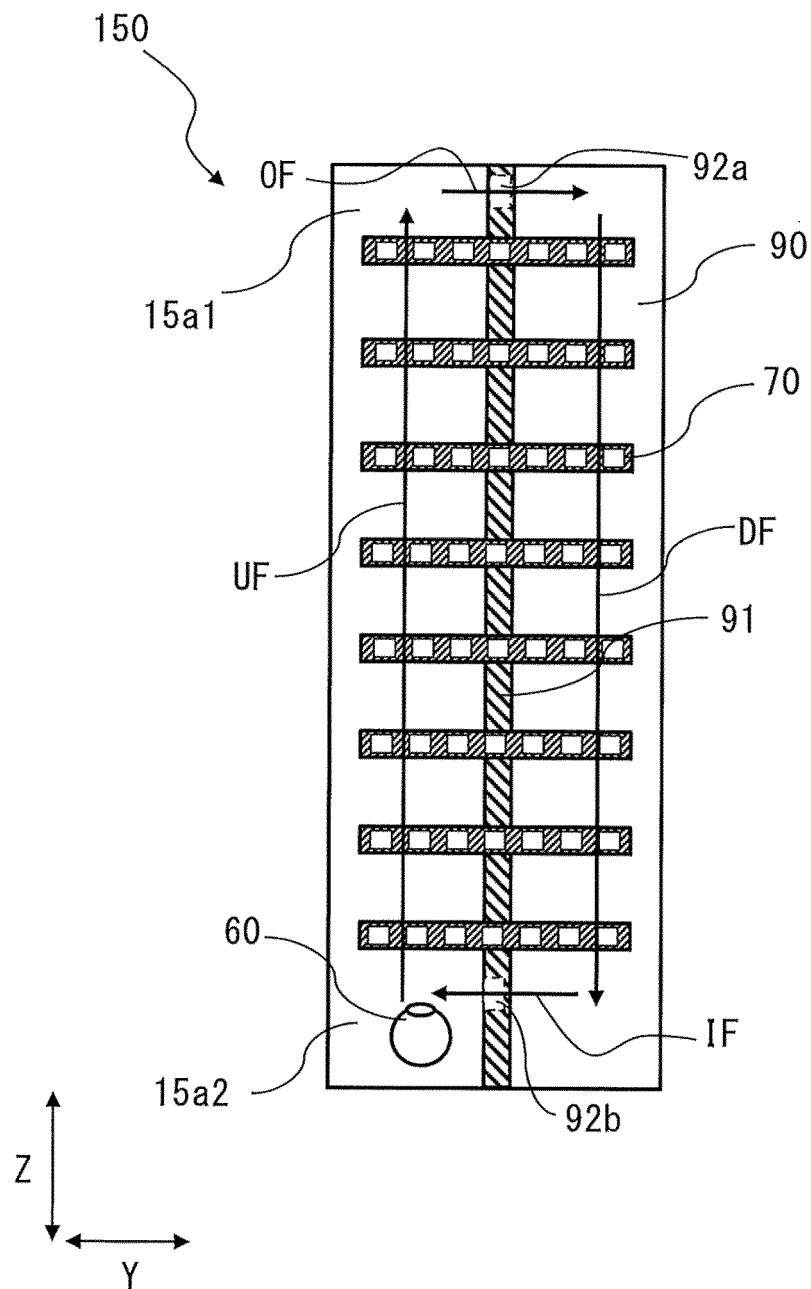


FIG. 23



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/002321

## A. CLASSIFICATION OF SUBJECT MATTER

F28F 9/02 (2006.01) i

FI: F28F9/02 301Z

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28F9/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------|-----------------------|
| X         | WO 2019/188828 A1 (DAIKIN INDUSTRIES, LTD.)                                        | 1, 9-10               |
| Y         | 03.10.2019 (2019-10-03) paragraphs [0039]-[0065],                                  | 8                     |
| A         | fig. 1-8                                                                           | 2-7                   |
| X         | WO 2018/116929 A1 (MITSUBISHI HEAVY INDUSTRIES                                     | 1, 9-10               |
| Y         | THERMAL SYSTEMS, LTD.) 28.06.2018 (2018-06-28)                                     | 8                     |
| A         | paragraphs [0022]-[0023], [0046]-[0049], fig. 1,                                   | 2-7                   |
|           | 15-20                                                                              |                       |
| X         | JP 2002-139295 A (TOYO RADIATOR CO., LTD.)                                         | 1, 10                 |
| Y         | 17.05.2002 (2002-05-17) paragraphs [0009]-[0012],                                  | 8                     |
|           | fig. 1                                                                             |                       |
| Y         | JP 8-233409 A (MATSUSHITA REFRIGERATION COMPANY)                                   | 8                     |
|           | 13.09.1996 (1996-09-13) paragraphs [0016]-[0022],                                  |                       |
|           | fig. 1                                                                             |                       |



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search  
25 February 2020 (25.02.2020)Date of mailing of the international search report  
10 March 2020 (10.03.2020)Name and mailing address of the ISA/  
Japan Patent Office  
3-4-3, Kasumigaseki, Chiyoda-ku,  
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/002321

| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                 |                       |
|-------------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                             | Citation of document, with indication, where appropriate, of the relevant passages              | Relevant to claim No. |
| A                                                     | US 2014/0123696 A1 (KIM, Hong-Seong) 08.05.2014 (2014-05-08) entire text, all drawings          | 1-10                  |
| A                                                     | WO 2019/087235 A1 (MITSUBISHI ELECTRIC CORP.) 09.05.2019 (2019-05-09) entire text, all drawings | 1-10                  |
| A                                                     | JP 2006-10262 A (DENSO CORP.) 12.01.2006 (2006-01-12) entire text, all drawings                 | 1-10                  |

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/002321

| Patent Documents<br>referred in the<br>Report | Publication<br>Date | Patent Family         | Publication<br>Date |
|-----------------------------------------------|---------------------|-----------------------|---------------------|
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| WO 2018/116929 A1                             | 28 Jun. 2018        | EP 3473963 A1         |                     |
|                                               |                     | paragraphs [0026]-    |                     |
|                                               |                     | [0032], [0067]-       |                     |
|                                               |                     | [0073], fig. 1, 15-20 |                     |
|                                               |                     | JP 2018-100800 A      |                     |
| JP 2002-139295 A                              | 17 May 2002         | (Family: none)        |                     |
| JP 8-233409 A                                 | 13 Sep. 1996        | (Family: none)        |                     |
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| JP 2006-10262 A                               | 12 Jan. 2006        | US 2005/0284621 A1    |                     |
|                                               |                     | entire text, all      |                     |
|                                               |                     | drawings              |                     |
|                                               |                     | DE 102005029171 A1    |                     |

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 2015068622 A [0004]